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U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 47, No. 5

MAY, 1919

WASHINGTON
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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological and seismological contributions and bibliography; (2) an interpretative summary and charts of the weather of the month in the United States and adjacent oceans; and (3) climatological and seismological tables dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; and (*b*) abstracts or reviews of important meteorological papers and books. In each issue of the REVIEW such contributions and abstracts are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather, applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Havana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

Supplements containing kite observations and others containing monographs are published from time to time.

SOME WEATHER BUREAU PUBLICATIONS.

A few of the more recent Weather Bureau publications are listed below, with their prices. A complete list may be obtained upon application to the *Chief, U. S. Weather Bureau.*

To secure such publications as have a price affixed, one should apply to and make remittances payable to the *Superintendent of Documents, Government Printing Office, Washington, D. C.* Stamps and personal checks are not accepted in payment. Additional charge for postage for foreign addresses.

National Weather and Crop Bulletin, with charts, monthly from October to March, weekly during remainder of the year	25c. a year.
Snow and Ice Bulletin, with charts, weekly during the winter	25c. season.
Climatological data, monthly for 42 separate sections, each section 5c. a copy	50c. a year.
Complete monthly number, 42 sections	35c. each, $4.00 year.
Monthly Weather Review Supplement No. 9. (Periodical events and natural law as guides to agricultural research and practice)	25c.
Monthly Weather Review Supplements Nos. 10 and 11. (Aerology Nos. 5 and 6), 1917 kite data	25c. each.
Monthly Weather Review Supplements Nos. 12 and 13. (Aerology Nos. 7 and 8), 1918 kite data, etc	25c. each.
Weather forecasting in the United States	$1.25
The daily weather map, with explanation (text and 4 charts)	5c.
Instructions for cooperative observers, 5th ed. Circulars B and C combined	10c.
Instructions for the installation and operation of Class A evaporation stations. Circular L	10c.
Papers on meteorology as a subject for study. (Repr. from Dec., 1918, Mo. Wea. Rev.)	10c.
Report of the Chief of the Weather Bureau, 1917–1918 (4° edition)	Free.
Modern methods of protection against lightning. (Farmers' Bull. No. 842)	Free.
Notes on the climate of France and Belgium	Free.
The Weather Bureau. (Descriptive pamphlet)	Free.
Explanation of the weather map (leaflet)	Free.
Serial numbers of Weather Bureau publications	Free.
General classification of meteorological literature (leaflet). (Repr. from Jan. 1919, Mo. Wea. Rev.)	Free.

As the surplus of MONTHLY WEATHER REVIEW SUPPLEMENT No. 2 is limited, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

CORRIGENDA.

REVIEW, January, 1919:

Page 29, second column, third line above the diagram, *for* "one-hundredths" *read* "one-hundredth."

Page 30, Table 2, Rio Grande, 1913, second column, *for* "5.544" *read* "5.844". Same table, Brazos Brook, 1909, fourth column, *for* "5.566" *read* "5.366". Same table, Gatun Lake, 1911, twelfth column, *for* "3.376" *read* "5.376."

[To face p. 279.]

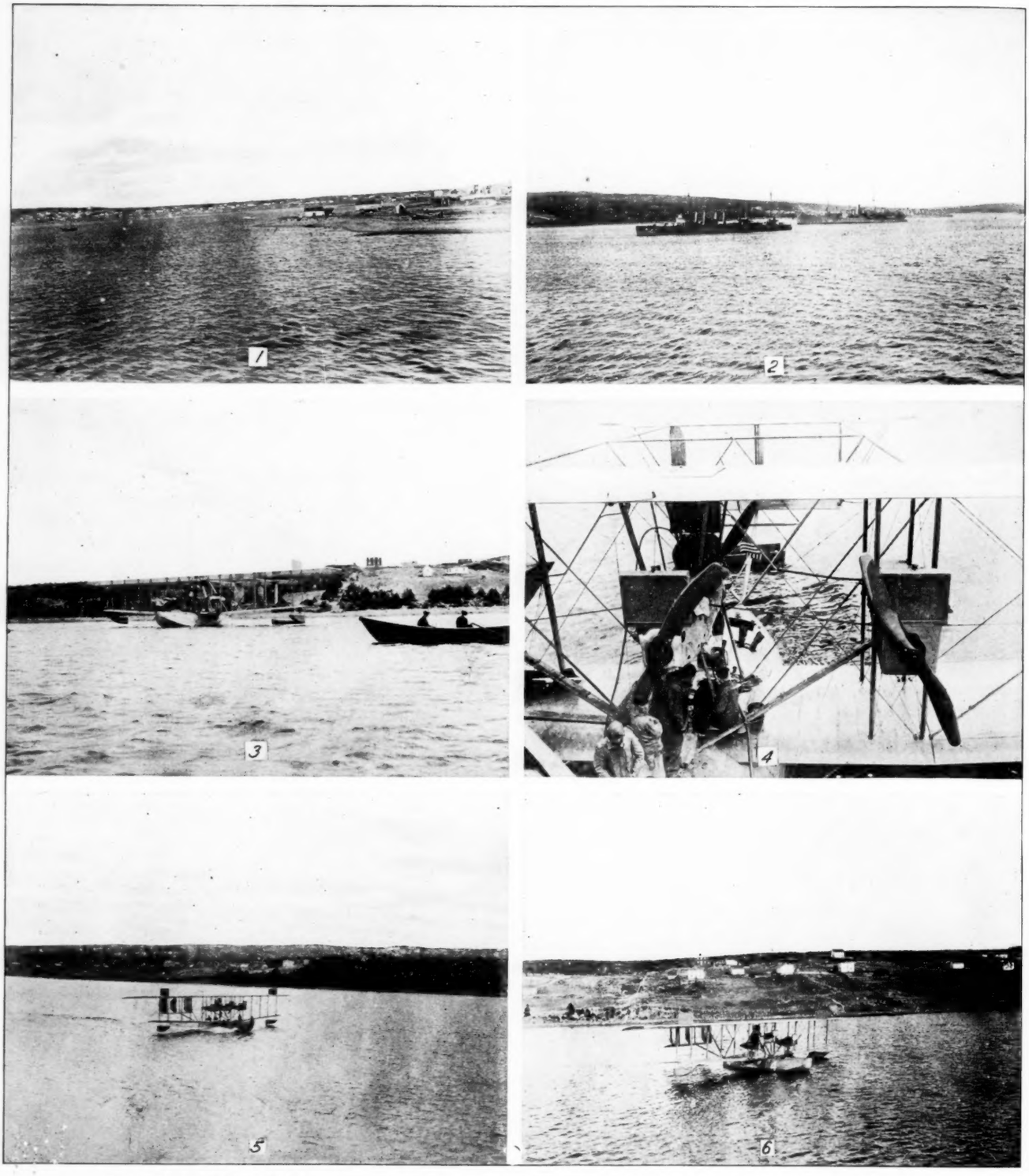

FIG. 1.—Trepassey Bay and village.
FIG. 3.—The NC-3 at her mooring, Trepassey Bay.
FIG. 5.—The NC-1 arrives at Trepassey Bay.

FIG. 2.—Group of destroyers. These, with others, furnished meteorological reports along the course of flight.
FIG. 4.—Close-up view of the NC-3.
FIG. 6.—The NC-4 "taxi-ing," preparatory to "taking the air" for flight to the Azores.

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CHARLES F. BROOKS, Associate Editor.

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THE FIRST TRANS-ATLANTIC FLIGHT.

By WILLIS RAY GREGG, Meteorologist.

[Dated: Weather Bureau, Washington, June 26, 1919.]

SYNOPSIS.—In connection with its trans-Atlantic flight the United States Navy, in cooperation with the Weather Bureau, arranged for meteorological reports from Europe, from the United States, and from ships at sea. These reports were forwarded by radio to the Weather Bureau at Washington, D. C., and to meteorologists, representing the Navy and the Weather Bureau, at Trepassey, N. F. Synoptic charts were regularly prepared, and forecasts furnished for the information of the aviators. Reports on May 16 indicated excellent conditions over the western part of the course, with parallel winds and clear weather; over the eastern part of the course, some cloudiness and possibly showers from low clouds, with little if any assistance from the winds; all in all, as nearly favorable conditions as could be expected for some time. The start was therefore made on that day. Reports of the seaplane commanders indicate that good flying weather prevailed, except near the Azores, where low clouds, fog, and some rain were encountered. The NC-4, however, arrived safely at Horta and later successfully completed its journey to Lisbon and Plymouth. So far as the meteorologist is concerned, the principal points brought out by this first trans-Atlantic flight are: (1) Necessity of greater accuracy in barometric observations; (2) the great value of free-air observations; (3) needed improvement in radio apparatus; and (4) importance of accurate and regular meteorological reports from merchant and other ships at sea for the benefit and information of all marine shipping and aviation interests.

The widespread interest in the United States Navy's attempt at trans-Atlantic flight and the general enthusiasm which greeted the success of that effort make it desirable that as complete a history as possible should be written of the undertaking, not only because of the importance of the lessons that have been learned, but also in order that future generations may have available a record of this epochal event, destined quite likely to assume a significance scarcely less momentous than that of Columbus' voyage across the seas. Official reports of the seaplane commanders will doubtless fully describe the planes themselves and all their equipment, the difficulties encountered, and the improvements necessary to overcome those difficulties in the future. The purpose of this sketch is to outline briefly the preparations that were made for receiving meteorological reports, to discuss the use to which those reports were put and to point out certain lines along which meteorological and aerological observation at sea should be developed.

During the winter months of 1919 plans were made by the Navy Department, in cooperation with the Weather Bureau, for securing as complete and widely distributed meteorological reports as possible. By special arrangement with the British Meteorological Office such reports were to be sent by radio from Carnarvon and were to include observations made in Iceland, the Scandinavian peninsula, the British Isles, Denmark, France, Spain, and Portugal. Similar reports were to be furnished from the United States, Canada, and the Bermudas. In addition, the Aerographic Division of the United States Naval Reserve Flying Corps, under the direction of Lieut. R. F. Barratt, organized a very complete system of observations to be taken on certain of the destroyers that were stationed along the line of flight from Trepassey, N. F., to Lisbon, Portugal, and on five battleships, three of which were stationed some distance north of the line of flight, and two a similar distance to the south of it. The locations of all these observing ships are indicated in figure 7. Their names and geographic coordinates are as follows:

Names.	Latitude, north.	Longitude, west.
BATTLESHIPS.		
Texas	46 56	31 01
Utah	50 25	39 40
Florida	36 00	42 00
Wyoming	40 00	52 00
Arkansas	48 00	12 00
DESTROYERS.		
Upshur	45 17	48 44
Walker	43 58	44 27
Meredith	42 38	40 15
Hopewell	41 19	36 08
Phillips	39 59	32 05
Gridley	38 58	29 12
Wilkes	37 58	21 01
Conyngham	38 13	16 46
Ericsson	38 29	12 34
Chew	45 36	7 16

ADDITIONAL "BASE SHIPS."

Baltimore at Halifax, N. S.
Aroostook at Trepassey, N. F.
Melville at Ponta Delgada, Azores.
Shawmut at Lisbon, Portugal.

The European reports included observations of pressure, wind direction and force, state of the weather, and barometric tendency; those from the United States and Canada, pressure, temperature, wind direction and force, state of the weather, and precipitation; and those from ships at sea, pressure, wind direction and force, barometric tendency, air and sea temperatures, state of the weather, state of the sea, visibility, amount, kind, and direction of clouds and upper-air wind conditions, as observed by means of pilot balloons. The European observations were taken twice daily, at 1 a. m. and 1 p. m., G. M. T.; the American observations, at midnight, noon, and 9 a. m., G. M. T. (8 p. m., 8 a. m., and 1 p. m. Washington summer time); and those at sea at 1 a. m., 7 a. m., 1 p. m., and 6 p. m., G. M. T. In all cases the reports were sent by radio, in accordance with schedules prepared by the Office of Naval Operations, to the Central Office of the Weather Bureau and to the base ship *Aroostook* at Trepassey, N. F. The reports began May 1 from Europe and America; May 7, from the battleships; and May 10, from the destroyers (fig. 2); in all cases continuing until the seaplanes left Trepassey, viz., May 16. Thereafter, reports were sent to Ponta Delgada only from Europe and from ships to the east and northeast of the Azores.

Observations on battleships and destroyers were taken by the enlisted personnel of the Navy. They were charted and studied, in connection with continental reports, by the official forecasters at Washington and by Lieut. Barratt, U. S. N., and the writer at Trepassey, N. F. Others who participated actively in this work, while the planes were at their respective stations, were Lieut. Commander Alexander McAdie at Halifax, Lieut. J. B. Anderson at Ponta Delgada, and Ensign F. W. Reichelderfer at Lisbon.

The reports received at Washington and at Trepassey enabled those engaged in their study to make fairly complete synoptic charts of weather conditions and to follow

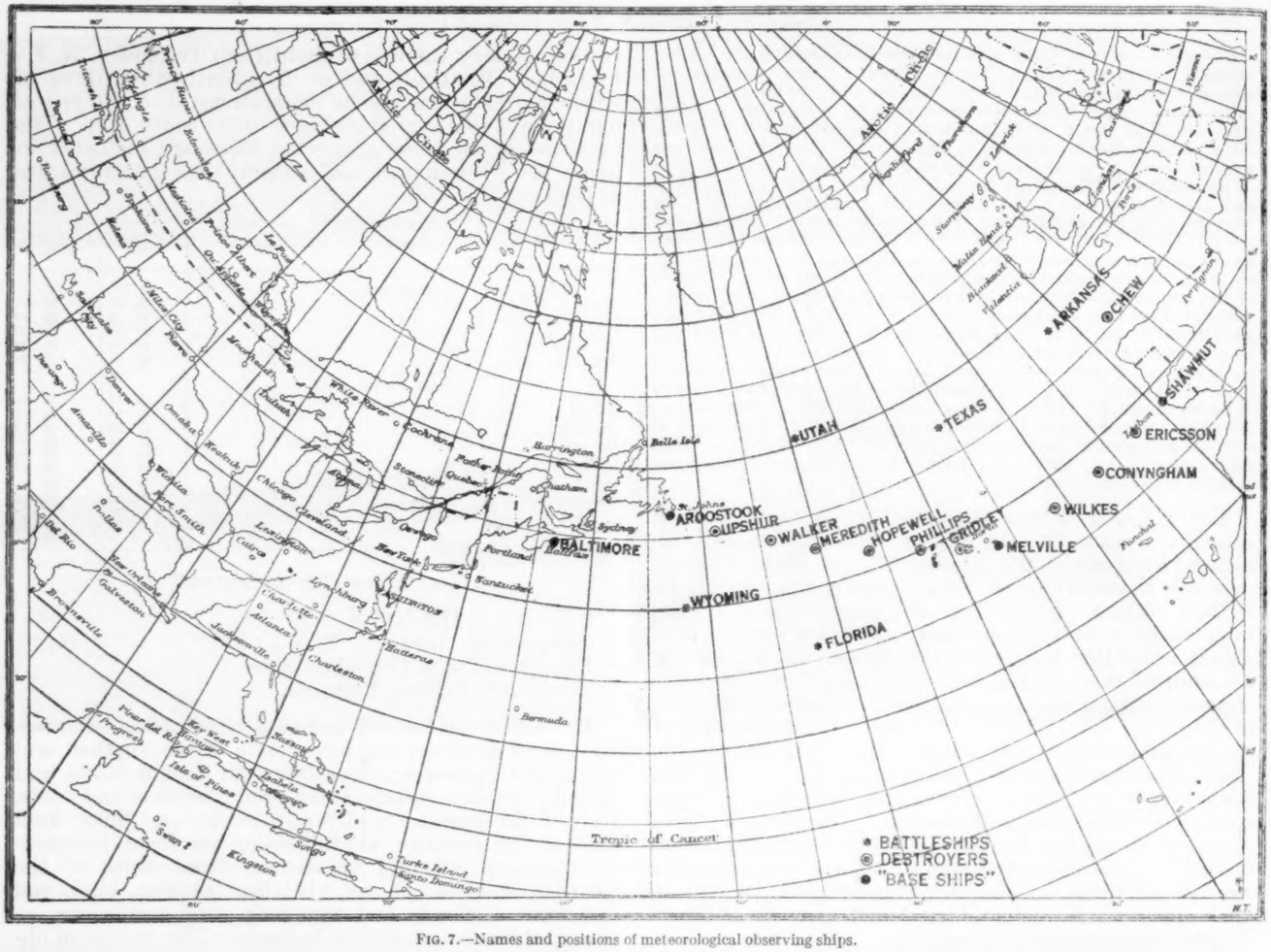

FIG. 7.—Names and positions of meteorological observing ships.

date as possible in order to have the advantage of bright moonlight; moreover, the destroyers would soon necessarily have to return for refueling; and it was desirable, if not essential, that the visibility be good, in order to render observations possible, and that the sea be not very rough, so that in case a descent were necessary the planes might not be wrecked before assistance could be summoned. It can thus readily be seen that a day might be so very favorable as to be absolutely *unfavorable*, for, with very strong winds, even though parallel to the course, the sea would be so rough as to make flying a risky experiment. A good example of this is afforded by a glance at the map showing conditions on May 12, Chart IX. On this date the winds were practically parallel to the course at all points along it, both at the surface and in the free air, yet reports indicated a sea of 3 to 8 meters and thus rendered a flight out of the question.

in detail the changes occurring in those conditions, with special reference to their bearing on the advisability of flight. The relative importance of the various meteorological elements, in determining whether or not conditions are favorable for flight, has already been discussed.[1] In the case of this particular undertaking there were certain special features that required consideration. For example, it was essential, on account of the great weight of the planes, that there should be a wind at Trepassey sufficiently strong to enable them to get off the water; it was essential also that the planes leave at as early a

Nevertheless, the two factors that were given closest study were wind assistance and state of the weather, or degree of storminess. The former was necessary, because of the limited cruising radius of the NC planes; and fairly clear weather was desirable, especially at night, in order that observations might be made for the purpose of determining geographic position. It was not expected (nor is it ever to be expected) that ideal conditions would at any one time be experienced over all portions of a course as long as this one. The problem, therefore,

[1] "Trans-Atlantic Flight from the Meteorologist's Point of View." MONTHLY WEATHER REVIEW, Vol. 47)65–75. See also "Air Navigation," by Maj. H. A. Wimperis, R. A. F., in Aeronautics, May 8, 1919, pp. 482–487, for a discussion of wind and fog, as affecting aviation in general.

was to select a day, as early as possible, on which reasonably favorable conditions would be encountered.

A discussion of the weather changes from day to day, together with forecasts issued from Washington, D. C., is given elsewhere in this REVIEW.[2] We shall now describe in somewhat greater detail the conditions on May 16. Observations at 1 a. m., G. M. T., showed generally unsettled conditions along the course, including light rain, some fog, and variable winds. By 7 a. m. these conditions had greatly improved, particularly over the western part of the course, where clear weather, westerly winds, good visibility, and smooth sea were reported. Still further improvement was shown by the reports at 1 p. m. Conditions were very nearly ideal at and near Trepassey; farther out there was cloudiness, and one ship reported rain. Unfortunately, no observations were received at this time from ships near the Azores, but the battleship *Florida*, lat. 36°, long. 42°, reported fairly high barometer, 30.20 inches, which, however, was apparently erroneous, as indicated by reports later received from that region. (See Chart XIV.) This inaccuracy in barometer readings was also apparent in the case of some of the destroyers' reports, with the result that it was impossible to compute with much certainty gradient wind values. Happily, though, pilot-balloon observations were available, and these indicated approximately the wind assistance that might reasonably be expected. Accordingly, the following statement was prepared at Trepassey and delivered to Commander Towers at 4 p. m., G. M. T.:

"Reports received indicate good conditions for flight over the western part of the course as far as Destroyer No. 12 (about 600 miles out). Winds will be nearly parallel to the course and will yield actual assistance of about 20 miles per hour at flying levels. Over the course east of Destroyer No. 12 the winds, under the influence of the Azores HIGH, recently developed, will be light, but mostly from a southwesterly direction. They will not yield any material assistance.

"Weather will be clear and fine from Trepassey to Destroyer No. 8 (about 400 miles out); partly cloudy thence to the Azores, with likelihood of occasional showers. Such showers, however, if they occur, will be from clouds at low altitudes, and it should be possible to fly above them.

"All in all, I believe that the conditions are as nearly favorable as they are likely to be for some time.

(Signed) "GREGG."

A table indicating in detail the wind assistance to be expected at various points along the route was also prepared and delivered to Commander Towers. Advice to start was likewise furnished at this time by Lieut. Barratt. The planes were then made ready, and definite word to attempt the flight was given by Commander Towers upon receipt of the following forecast from Washington at 6.30 p. m., G. M. T.:

"Surface winds fresh and possibly strong west-southwest and upper winds fresh to strong west over course between Newfoundland and Azores. Some clouds, fair visibility, and rising pressure. Conditions favorable for start.

(Signed) "BOWIE."

As is well known, the start was made that evening. After "taxi-ing" in the harbor for some time in order to warm up the engines and to see that everything was functioning properly, the planes headed into the wind, which was blowing at 15 to 20 miles per hour, and left the water in the following order: NC–3 (figs. 3 and 4), Commander John H. Towers in charge, at 10:04 p. m., G.M.T.; NC–4 (fig. 6), Lieut. Commander Albert C. Read in charge, at 10:05 p. m.; and NC–1 (fig. 5), Lieut. Commander P. N. L. Bellinger in charge, at 10:10 p. m. To those who were privileged to witness it, the event was one of absorbing and dramatic interest. So much time and earnest effort had been spent in preparation that all felt the project *must* succeed, yet the vagaries of fortune play so prominent a part in *all* undertakings that the feeling of pride with which the successful departure was watched was coupled with a feeling of anxiety lest some feature might have been overlooked that would spell disaster. Most of the spectators had played a more or less prominent part in carrying out the details of preparation and therefore realized keenly their proportionate share of the responsibility; perhaps none more so than those to whom the meteorological work was assigned. Knowing full well that conditions were not perfect, they nevertheless believed that those conditions were more nearly favorable than would be encountered for some time at least. An examination of reports later received for the remainder of the month indicates that this belief was well founded.

There were some spectators, however, who felt none of this responsibility but only a sense of keenest interest and expectancy. These were the good people of Trepassey, experts in deep-sea fishing, to whom the events of this period, from the arrival of the *Aroostook*, Capt. J. H. Tomb, commanding, on May 2 to the departure of the planes on May 16, formed a succession of thrills and surprises quite demoralizing to the daily routine of life. Rarely, if ever, has it been given to the inhabitants of a small hamlet (figs. 1 and 2), whose previous history had been of so quiet and retiring a nature (at any rate since the days two or three hundred years ago when the almost land-locked harbor of Trepassey formed a safe retreat for the rugged crews of pirate ships) to become all at once the center of world interest. That they appreciated their good fortune was evident not only in their display of friendly curiosity, but also in the cordiality with which they greeted and chatted with their unexpected and uninvited guests. True, this interest was not entirely impersonal, for business in Trepassey suddenly underwent a very striking transformation. It was reported, for example, that the local telegraph office sent more words during this two-week period than during the previous 20 years or than it was likely to send for the next hundred years.

The three seaplanes, as soon as they had "taken the air," flew seaward down Trepassey Bay, then turned eastward and were soon lost to view. By means of radio, however, information as to their progress was available for the next several hours. At 1:23 p. m., G. M. T., May 17, the NC–4 arrived at Horta, having covered the distance of 1,200 nautical miles (1,380 statute miles) in 15 hours and 18 minutes, at an average speed of 78.4 knots (90 miles per hour). The average airspeed of the machine itself has not been reported, but it was probably not greater than 70 to 75 miles per hour, and it is evident, therefore, that the wind assistance amounted to about 15 to 20 miles per hour. The following references to weather conditions are taken from Lieut. Commander Read's story of the NC–4's flight:

"The NC–3 left the water at Trepassey Bay at 10:04 p. m., G. M. T.; the NC–4 at 10:05 p. m., and the NC–1 some time later (10:10 p. m.).

[2] E. H. Bowie, Weather Warnings, p. 347. This also discusses weather conditions during the flights from Rockaway, Long Island, to Trepassey, N. F., and during the flight of the Navy dirigible C–5 from Montauk Point, Long Island, to St. Johns, N. F.

"We were flying over icebergs, with the wind astern and the sea smooth.

"It was very dark, but the stars were showing. At 12:19 on the morning of the 17th the May moon started to appear, and the welcome sight made us all feel more comfortable.

"Each destroyer was sighted in turn, first being located by star shells, which, in some cases, we saw forty miles away; then by the searchlights, and finally by the ships' lights. All were brilliantly illuminated.

"So far, our average speed had been 90 knots, indicating that we had a 12 knot favorable wind. At 1:24 the wind became less favorable and we came down to 1,000 feet.

"At 5.45 we saw the first of dawn. * * * Messages were received from over 1,300 miles, ——

"At 8 o'clock we saw our first indications of possible trouble, running through light lumps of fog. It cleared at 8:12, but at 9:27 we ran into more fog for a few minutes. At 9:45 the fog became thicker and then dense. The sun disappeared and we lost all sense of direction. The compass spinning indicated a steep bank, and I had visions of a possible nose dive.

"Then the sun appeared and the blue sky once more and we regained an even keel and put the plane on a course above the fog, flying between the fog and an upper layer of clouds. We caught occasional glimpses of the water, so we climbed to 3,200 feet, occasionally changing the course and the altitude to dodge the clouds and fog.

"We sent out a radio at 10:38 and at 10:55 to the nearest destroyer, thinking the fog might have lifted. We received replies to both messages that there was thick fog near the water.† At 11:10 we ran into light rain for a few minutes.

"At 11:13 we sent a radio to the destroyer and could hear Corvo reply that the visibility was 10 miles. Encouraged by this promise of better conditions further on, we kept going. Suddenly, at 11:27 we saw through a rift what appeared to be a tide-rip on the water. Two minutes later we saw the outline of rocks.

"We glided near to the shore and rounded the point. Finding that the fog stopped 200 feet above the water†, we shaped our course for the next destroyer, flying low, with a strong wind behind us. We sighted No. 22 in its proper place at 12 o'clock. This was the first destroyer we had seen since we passed No. 16.

"The visibility then was about 12 miles. We had plenty of gasoline and oil and decided to keep on to Ponta Delgada. Then it got thick and we missed the next destroyer, No. 23. The fog closed down * * *

"At 1:04 we sighted the northern end of Fayal, and once more felt safe.

"We headed for the shore, the air clearing when we neared the beach. We rounded the island and landed in a bight we had mistaken for Horta.

"At 1:17 we left the water and rounded the next point. Then we sighted the Columbia through the fog and landed near her at 1:23.

"Our elapsed time was 15 hours and 18 minutes."

The NC–1 and the NC–3 made practically the same time (and experienced therefore similar weather conditions) as did the NC–4. Near the Azores, however, in order to get their bearings, they descended to the surface, landing at about 1 p. m., G. M. T. The water was too rough to enable the planes to resume the flight, and considerable damage was done to them. Fortunately the NC–1 was able to get in communication with a passing vessel, and the crew were rescued, although the plane itself was lost. Because of a defect in its radio apparatus the NC–3 was unable to inform the destroyers or other ships of its plight and was therefore compelled to make headway as best it could. This was difficult, owing to the southward extension, on the 18th (see charts XV and XVI) of a cyclonic disturbance that had previously been central at about latitude 50° N., longitude 30° W. In spite of the high winds and seas resulting from this storm, the NC–3 succeeded in "taxi-ing" to Ponta Delgada, reaching that harbor on May 19.

On May 20 the NC–4, assisted by strong west-northwesterly winds, flew from Horta to Ponta Delgada, covering the distance of 150 nautical miles (173 statute miles) in 1 hour and 45 minutes, at an average speed of 86.7 knots (100 miles per hour). During the following week the weather between Ponta Delgada and Lisbon was generally unfavorable with head or cross winds and more or less cloudiness. On May 27 winds practically parallel to the course prevailed at all points (see chart XVIII) and the trans-Atlantic flight was successfully completed, this portion of the journey, 800 nautical miles (920 statute miles) being made in 9 hours and 44 minutes, at an average speed of 82.1 knots (95 miles per hour).

The most important lessons drawn from this first successful aerial crossing of the Atlantic, so far as the meteorologist is concerned, are:

1. Decided improvement in marine barometers and greater care in reading them (probably the latter in most cases) is necessary. Inaccurate pressure reports frequently made it impossible to determine the gradient existing at different points along the route, and in one case, previously referred to, indicated a condition the exact reverse of that actually prevailing.

2. The great value of free-air observations, in this case with pilot balloons, was clearly demonstrated. Without these observations it would have been impossible, owing to the inaccuracy of the barometric reports, to have indicated what wind conditions were to be experienced.

In reply to a reporter's question, "Did you find the weather reports important and reliable?" Lieut. Commander Read on his return to the United States said, "We found them very important. The Weather Bureau has a good system of reporting direction and velocity of surface winds, but no facilities for making observations of winds at high altitudes. That is something which might be developed if the Weather Bureau should have the money appropriated." (N. Y. Ev. Post, June 28, 1919, sec. 2, p. 4.)

3. The development of radio apparatus capable of covering greater distances and of avoiding interferences is essential.

4. The maintenance of "station" ships at sea is expensive and perhaps impracticable, but it should be possible to organize on a large scale a cooperative service, whereby all merchant and other ships should at stated times furnish accurate and prompt reports of meteorological conditions at sea, these reports to be received at land stations, where they can be charted and studied for the benefit and information of all marine shipping and aviation interests.

† Technically "fog" rests on the surface, so this was a low cloud.—ED.

‡ This is literally true, but the goal set by the Navy Department was Plymouth, England, and this was reached on May 31. The NC–4 flew from Lisbon to Ferrol Harbor in the northern part of Spain, on the 30th and completed the journey on the following day. Charts XXI and XXII show generally fair weather along the line of flight, with practically no wind, on those two days. On the 31st, however, some fog and local showers were encountered, and it was therefore necessary to fly at a very low altitude, much of the time at about 100 feet.

THE FLIGHT OF HAWKER AND GRIEVE.

On May 18, 1919, at 5.45 p. m., G. M. T., Mr. Harry G. Hawker and Commander Mackenzie-Grieve left St. John's, N. F., for a nonstop flight direct to Ireland. For several days no news of them was heard, but on May 25 the world was electrified to learn that these daring aviators had been rescued at sea by a Danish steamship. Mr. Hawker told his story simply as follows: [1]

"We had very difficult ground to rise from on the other side. To get in the air at all we had to run diagonally across the course. Once we got away we climbed very well, but about 10 minutes up we passed from firm, clear weather into fog.

"Off the Newfoundland banks we got well over this fog, however, and of course at once lost sight of the sea. The sky was quite clear for the first four hours, when the visibility became very bad. Heavy cloud banks were encountered, and eventually we flew into a heavy storm, with rain squalls.

"At this time we were flying well above the clouds at a height of about 15,000 feet.

"About five and one-half hours out, owing to the choking of the filter the temperature of the water cooling out the engines started to rise, but after coming down several thousand feet we overcame this difficulty.

"Everything went well for a few hours, when once again the circulation system became choked and the temperature of the water rose to the boiling point. We of course realized that until the pipe was cleared we could not rise much higher without using a lot of motor power.

"When we were about 10½ hours on our way the circulation system was still giving trouble, and we realized we could not go on using up our motor power.

"Then it was we reached the fateful decision to play for safety. We changed our course and began to fly diagonally across the main shipping route for about two and a half hours, when, to our great relief, we sighted the Danish steamer, which proved to be the tramp *Mary*.

"We at once sent up our Very light distress signals. These were answered promptly, and then we flew on about two miles and landed in the water ahead of the steamer.

"The sea was exceedingly rough and despite the utmost efforts of the Danish crew it was one and one-half hours before they succeeded in taking us off. It was only at a great risk to themselves, in fact, that they eventually succeeded in launching a small boat, owing to the heavy gale from the northeast which was raging.

"Altogether, before being picked up, we had been 14½ hours out from Newfoundland. We were picked up at 8:30 (British summer time)."

Commander Mackenzie Grieve, the navigator of the Sopwith, said:

"When but a few hundred miles out a strong northerly gale drove us steadily out of our course. It was not always possible, owing to the pressure of the dense masses of cloud, to take our bearings, and I calculate that at the time we determined to cut across the shipping route we were about 200 miles off our course.

"Up to this change of direction we had covered about 1,000 miles of our journey to the Irish coast. [The landing was made in latitude 50° 21′ N., and longitude 29° 30′ W.]"

During much of the time a straight course could not be steered because of clouds. In this way much time was lost, so it is not surprising that a speed of only about 80 miles an hour (1,050 statute miles in 13 hours) was, on the average, maintained. Very likely, however, this loss in speed was due in no small measure to the fact that cross winds prevailed during the greater portion of the flight. The air speed of the Sopwith machine is not known, but it was probably about 90 miles an hour, and the course of flight was on the average E. 15° N. If we assume that the wind blew approximately at right angles to the course with a speed of 40 miles per hour (and this is a fair assumption, judging from reports published [1]) we find that the machine, in order to follow the desired course, would have to make an angle with it of about 26½°, and the resultant speed would be only 81 miles per hour. Under the conditions of speed above given, i. e., wind 40 miles per hour and airplane 90 miles per hour, what might be called the wind's *critical* angle, or an angle with the course such that neither assistance nor resistance would be offered, is about 78°.[2]

A discussion of Alcock's and Brown's successful nonstop trans-Atlantic flight will appear in the June, 1919, number of the MONTHLY WEATHER REVIEW.—*W. R. Gregg.*

[1] New York Times, May 27, 1919, by courtesy of the London Daily Mail.

[1] See also Charts XV and XVI in this number of the Review.
[2] Cf. MONTHLY WEATHER REVIEW, February, 1919, p. 70.

A NEW EVAPORIMETER FOR USE IN FOREST STUDIES.

By C. G. BATES.

[Dated: U. S. Forest Service, Denver, Colo., April, 1919.]

SYNOPSIS.—This article treats of the subject of evaporation or transpiration from plants, of the factors which influence it, and of the conditions which must be met before water losses from plants can be approximately determined through instrumental evaporation.

It is pointed out that the "evaporation stress" or tendency to evaporate, is produced by a different combination of factors in each body from which evaporation may occur. Because of the fact that the vaporizing process in leaves takes place on the surface of moist cell walls which are not directly exposed to the moving air, the theory would lead us to expect that the effect of wind would be greatly minimized in evaporation from leaves, the rate of diffusion of the vapor being almost completely controlled by vapor pressures in the leaf (inter-cellular) spaces. On the other hand, the leaf is admirably adapted for absorbing the sun rays of all wave lengths; hence evaporation from leaves will be more directly controlled by the supply of radiant energy than perhaps will that from a body which does not absorb so readily and which may obtain considerable heat from the air, especially if a strong wind brings new supplies of air rapidly to the evaporating surface.

The article then describes the efforts which were made to devise an instrument having about the same relation to wind and to radiant energy as do leaves of plants in general. The idea of an "inner cell" for the vaporizing process, rather than a freely exposed moist surface, was the basis for these efforts. The result was a very practical metallic instrument known as the "Type 4 evaporimeter," whose behavior and operation are fully described. The essential feature of this instrument is a moist layer of linen between two metal plates, the upper of which protects the wick from rain, is coated with lampblack and transmits absorbed heat to the wick; the lower plate is thick and contains a number of small perforations simulating the stomata of leaves. Vapor formed in the moist linen escapes through these perforations. The layer of linen is above a well-insulated tank, from which it is fed by a stem wick. Distilled water is used and evaporation losses are obtained by weighing before and after exposure.

It is shown that considering either a large number of daily periods having a variety of weather conditions, or shorter periods at different times of the day, the evaporation from the Type 4 evaporimeter parallels the total transpiration of 12 small coniferous trees more closely

than does the evaporation from other instruments commonly used in ecological study, or the earlier types which led up to Type 4. "The others show wider variation (from the plants) about in proportion to the degree in which they expose the evaporating surface to moving air, and fail to absorb fully the heat of sunlight."

This parallelism between plants and the new instrument comprises the sole technical argument in favor of its use, at the same time demonstrating the correctness of the theory on which the instrument was constructed.

On the other hand, the new instrument has an apparently objectionable feature in exposing a horizontal surface to evaporation. This, it is shown, may possibly be an advantage, if, as it appears, plant activity becomes less as the season advances, and the instrument at the same time exposes its absorbing surface less squarely to the sun's rays.

In the closing paragraphs the practical features of the instrument are stressed, and precautions in its use are given.

INTRODUCTION.

The purpose of the present paper is to describe the construction, behavior, and operation of a new evaporimeter or atmometer which has been designed particularly for studies in forest ecology, but which may find a wider field of usefulness. Before attempting such description it will be well to outline some of the theoretical and practical considerations which have led to the development of this instrument.

Perhaps the only respect in which forest studies demand a different treatment from other ecological studies, is in the year-long observations, necessitated by the perennial nature of the plants involved. Because of this there seemed to be demanded an evaporimeter which could be used under any weather conditions. Results already secured, and soon to be published(1), fully justify the assumption that winter records of evaporation are necessary for an understanding of forest problems.

PURPOSE OF EVAPORATION MEASUREMENTS.

It is presumed that there is a common object in most measurements of evaporation, whether made for purely climatological purposes, or in connection with ecological or physiological studies of plants or animals, namely, to secure an integration of the effects of all those factors which contribute to evaporation, any or all of which might be independently measured more precisely and almost as readily as evaporation itself, but which vary in their combined action to such an extent that no formula has ever satisfactorily integrated them even with relation to evaporation from bodies of free water.

As the present writer understands the matter, evaporation with respect to animals is of greater importance in effecting sensible temperatures than in effecting direct water-loss; with respect to soils, there is no constant evaporation problem in agriculture, because soil evaporation can be very largely controlled by cultivation, and in forestry there is likewise no constant soils problem, because the forest soil may be well or poorly protected by a mulch. The big, outstanding problem, susceptible of instrumental treatment, therefore, for ecologists, and for climatologists whether they will it or not, is the problem of the water-loss from plants to the atmosphere, and it is only with this problem that we propose to deal. Nothing will be gained by trying to combine this problem with that of evaporation from reservoirs, soils, etc.

Even this problem is not so simple as it would at first seem, for it is realized that no two plants, no two leaves of the same plant, will respond to evaporation stimuli in exactly the same way. Atmometry, at the best, must be only an approximate method for determining the reaction of the plant in the matter of transpirational water-loss. What it really aims to do is to integrate all of the factors which contribute to evaporation as nearly as possible in the same way that the plant integrates these factors. It is obvious that the goal can always be only approached, never reached, but this is no reason for failure to progress. It is almost absurd, for example, to measure evaporation for biological purposes in terms of a free-water surface, which is much more strongly influenced by wind movement, and less directly affected by solar radiation, than the plant.

Hereafter we shall speak of the total integrated value of the factors which contribute to evaporation as the "evaporation stress." This is not alone the product of atmospheric factors, for it includes as well the temperature of the body evaporating, as influenced by the supply of solar heat. It is therefore evident that the evaporation stress, for a given set of conditions, may be as variable as the kinds of bodies from which evaporation occurs. It is simply a convenient name for any integration. It seems to be necessitated by the fact that instrumental evaporation should be analyzed, that there should be a common basis for comparing evaporation with transpiration, and there should be a basis for determining whether a plant is evaporating in proportion to the stress existing, or possibly is holding up transpiration by some protective device.

THE COMPONENTS OF EVAPORATION.

The object here is simply to treat the factors which contribute to evaporation qualitatively, and not to devise a formula, but to make certain that no important item is overlooked.

The maintenance of a given rate of evaporation is dependent primarily upon the heat available for vaporization, while the rate of diffusion of the vapor from the evaporating body really controls the evaporation rate when other factors are constant.

In the case of the plant, heat is derived from radiation, direct or reflected sunlight being of the greatest importance; and from the air in contact with the plant.

In the case of the plant, again, the rate of diffusion of the vapor may be considered as a function of the differential vapor pressure between the intercellular spaces of the leaf and the atmosphere immediately surrounding the mouths of the stomata. The former may be considered for all practical purposes as the pressure of saturated vapor at the temperature of the leaf; the latter will be essentially the vapor pressure of the atmosphere, though slightly modified by the possible accumulation of vapor about the mouth of the stomata, and the aid to diffusion furnished by air movement or wind. There is some reason for supposing that the function of wind in aiding diffusion has been greatly exaggerated; that its primary effect on evaporation arises from the supplying of heat. There can be little doubt but that vapor molecules, when they become mixed with the molecules of the moving air, are set in motion in the prevailing direction, in spite of the molecular independence of the two kinds of gases. Both theory and experience, however, point to the hypothesis that when air is moving horizontally over a water surface it must aid materially in carrying the vapor molecules out of the zone from which they might readily return to the water mass; but when blowing over the surface of a leaf the air encounters only molecules which are measurably removed from the water mass, already moving away from it in the normal process of diffusion, and not likely to be diverted from that course. Of the molecules likely to enter the stomata the wind would, theoretically, not remove any more than it brought into range. At the best, then, wind movement simply aids to clear congestion around the stomata, and has no effect

on the initial direction or velocities of the molecules as they are set free from the moist walls of the internal cells.

Heat required for evaporation.—By all odds the most important question in evaporation is the source and amount of the heat available for it; for, if heat is not supplied to the evaporating body, its temperature must quickly fall below that of the air and evaporation will approach the zero rate as the temperature of the body approaches that of the dew point.

The amount of heat required to evaporate a gram of water at the boiling point is about 537 calories, but the amount is greater at lower temperatures, and for ordinary purposes we may consider it as being 600 calories. The amount required to evaporate from an aqueous solution, such as the cell sap of the plant, is even greater, probably in most plants about 700 calories per gram.

As has been stated, most of this heat must be derived from direct solar radiation. The leaf is eminently adapted to absorb nearly all of the energy of the sunlight which falls upon it. The red and infra-red or "dark" rays, which possess a large part of the heat energy, are readily absorbed by the water and cell walls of the leaf. Some of the visible light escapes. The ultra-voilet portion of the spectrum may be considerably absorbed by the chloroplasts, but we shall consider that this energy is all used in photosynthesis. Of the total energy of sunlight about 2 calories per square centimeter per minute at outer limits of atmosphere, there should be available for evaporation or heating, after making all allowances, possibly 1 calorie. To evaporate at the rate of 1 gram of water per hour, requiring say 700 calories, the leaf would therefore only have to expose about 12 square centimeters normally to the sun's rays.

If the same amount of heat were to be supplied by conduction from the air, it would be necessary that 2 cubic meters of air should come in contact with the leaf every hour, assuming that the air were only 1° C. warmer than the leaf. And, assuming that in passing over the leaf a layer of air 1 mm. thick might transmit all its surplus heat to the leaf, there would be required a velocity of between 30 and 40 miles per hour to bring this volume of air within effective distance of the leaf. This calculation simply serves to accentuate the importance of sunlight as a source of heat for transpiration and to show how impotent the only other possible source would ordinarily be.

Conversely to the previous proposition, if the conditions in the leaf were such, and the humidity of the atmosphere were so high, that evaporation did not occur readily, the temperature of the leaf might be higher than that of the air, and air movement would tend to carry away heat from the leaf, to just the same extent that it has been shown to be a possible source of heat. Under such circumstances the effect of wind in helping to diffuse vapor, we have reason to believe, is just about neutralized, and wind may, therefore, when the vapor pressure within the leaf is barely higher than that of the outer atmosphere, be non-effective in producing evaporation.

There is another relation of heat to evaporation which I have never seen discussed. The velocities of vapor molecules, and the resultant rates at which they will diffuse from the intercellular spaces to the outside air, do not increase as rapidly as their temperatures. At the same time, other conditions remaining the same, a higher leaf temperature must mean a larger supply of heat, and a greater number of vapor molecules set free each moment. In the inter-cellular spaces of the leaf, with a rising temperature, due to steadily increasing insolation, we therefore have this condition: The number of molecules set free from the liquid increases, the repulsion between the molecules also increases, each requiring more space; there is set up within the leaf an accumulated vapor pressure, causing a discharge in excess of the normal rate of diffusion for the current temperature; equilibrium with the outside vapor pressure can only be maintained by a rate of diffusion somewhat greater than the rate of vaporization. When the heat supply and temperature are declining there will be reversal of this process—to store vapor. The result is simply this: That the rate of transpiration is higher when the temperature of the leaf is rising, than with the temperature declining, external vapor pressures, etc., being equal. It would not appear that the storage space in the leaf was sufficient to make this an important item. Yet such a conception seems necessary to account in part for higher transpiration rates, generally, in the morning than in the afternoon, for equal temperatures, vapor pressures, etc.

It is fairly obvious that this condition may not be duplicated in the layer adjacent to a free-water evaporating surface, because there is here no tendency for vapor to accumulate on account of inadequate avenues for escape. The phenomenon in the leaf is dependent upon the agency of the inner cell which stands between the evaporating surface and the outer air, and it therefore becomes apparent that an atmometer, if it is to follow the ups and downs of transpiration, must, like the leaf, have some space for the storage of vapor.

CONSIDERATIONS LEADING TO DEVISING OF NEW INSTRUMENT.

The matters which have just been mentioned appear to be purely theoretical, and they are that. They represent an attempt to place observed phenomena within the confines of some generally applicable hypothesis.

For the most part the phenomena which led up to this statement of the theory of evaporation and transpiration came to the writer's attention, in the form of Burns's work on the "Tolerance of New England Forest Trees," (**2**) just at the moment when he was struggling with the practical features of evaporation measurements. The observation regarding the relation of transpiration to differential vapor pressures is based on a long series of measurements by the writer, in 1917. These are soon to be published.

Among the points enumerated by Burns in his "Conclusions," and fully corroborated by his data, are the following, which seem to have a bearing on the present problem. The parenthetical elaborations are mine:

"2. When all of the factors affecting evaporation and transpiration agree (that is, all tend toward an increase or a decrease simultaneously) the black and white atmometers and plants agree (that is, increase or decrease together)."

"3. When certain factors are very marked (that is, when one or more are strongly predominant over others which might influence adversely) both instruments and plants agree.

"4. When the factors vary, some plus and some minus, the responses of the instruments and plants disagree, because both black and white atmometers and plants are affected differently by different factors.

"8. Plants normally reach the maximum water loss in the morning. If, however, the meteorological conditions are decidedly more favorable to water losses in the afternoon, the maximum loss may occur later in the day. (On normal days, in the above sense, when sunshine is

essentially the same morning and afternoon, and the afternoon temperatures are higher, the relative humidity lower, with consequent higher deficit, the transpiration is markedly less in the afternoon than in the morning, while evaporation is usually somewhat greater).

"10. The effect of half-shade upon the plants is more marked than upon the instruments (in reducing losses).

"11. Evaporation-transpiration coefficients based on unit of dry weight of plants for no-shade, half-shade, and full-shade beds show that the response of the plant agrees more closely with the black atmometer than the white atmometer."

For present purposes these conclusions might be summed up as follows: The plants (tree seedlings) in their transpiration show greater dependence upon light than do the atmometers; the plants and black atmometer agree more closely than the plants and white atmometer because the black atmometer absorbs the more light of the two; because neither atmometer absorbs radiant energy as fully as the plants, or uses it so effectively to supply heat for vaporization, both show greater dependence for evaporation upon the temperature, humidity, and movement of the air than do the plants.

These technical considerations led to the decision to construct an atmometer which would be as sensitive as possible to sunlight effects, through complete absorption of the rays, and which should at the same time be less subject to the influence of the moving air, by exposing the evaporating surface within a chamber which should have only a small opening to the outer atmosphere. Thus, the desire to attain certain physical relations led to a mechanical construction somewhat similar to that of the leaf and gave rise to the name "inner-cell evaporimeter."

The practical consideration which led to the same end were mainly those brought out by the attempt to use existing atmometers for winter measurements. The Piche instrument had been very extensively used both winter and summer; in the winter by filling with an alcohol solution which could only be compared in evaporating rate with water, and not with ice; during the summer with the innumerable difficulties of overflowing in damp weather, and drying out or exhausting its water-supply in warm weather, under the necessary program of daily observations and adjustments. The Livingston porous cup had been tested in more expert hands and had demonstrated its utility and sensitiveness under growing season conditions, but with the first appearance of frost ceased to be serviceable. This technical feature of the porous cup and other objections to the then existing precise atmometers have been so fully explained by Livingston, (3) that it does not seem worth while to dwell upon their merits and demerits here. There is one additional point about the Livingston cup, however, which promised to be very troublesome in forest studies, where it is not always feasible to furnish protection against hail and other injury by the elements, or against squirrels, deer and other animals that will nose about. This is the fragile nature of the Shive non-absorbing apparatus, which must be used to obtain good results.

DEVELOPMENT.

The first effort to devise a more practical instrument for our field conditions, and for situations where infrequent visits were the rule, was made in the fall of 1915. This instrument did not possess any new physical features, but attempted to make use of the capillary properties of cotton wicking to overcome the feeding difficulties of the Piche instrument. In the top of a metal tank, which presented a flat surface designed always to be horizontal, two slits were made about 5 centimeters long and 5 centimeters apart, such that the ends of a strip of 2-inch wicking could be thrust through them, reaching down into the water in the tank. When drawn taut, there would be exposed on the top of the tank an evaporating surface of about 25 square centimeters. The tanks were designed to hold over a liter of water. They were provided with drain cocks, and the plan was to fill the tank at each observation with the contents of a liter-flask; after a period of evaporating, the water would be drawn off into the flask, and a graduate used to again fill the flask to capacity, thus obtaining a measure of the amount lost in the evaporating period. This method was, of course, slow, very difficult to carry out in freezing weather, and subject to the errors of all volumetric determinations under varying temperature conditions. The tanks, moreover, to withstand the pressure of ice had been made so heavy as to make close weighing in the field impracticable. The cotton wicking had abundant capillary capacity so long as it remained moist; drying out in freezing weather, however, it usually failed to remoisten itself. The comparisons between a shaded instrument and one fully exposed to the sun, were, moreover, very disappointing, and failed to bring out one of the secondary objects of the measurements, which was to obtain a measure of sunlight heating values. Not infrequently the insolated wick evaporated, in a strong wind, less than the shaded one. This could be interpreted as evidence that slight superheating of the wick above air temperature tended to eliminate air conduction as a source of energy for evaporation. It is possible that the shading device tended somewhat to increase the air current over the shaded wick. Even granting this, however, it becomes evident that the comparison of shaded and insolated, or black and white atmometers, can not possibly give a measure of sunlight intensities.

While these tests were being made, the theory of plant evaporation was becoming clarified and another plan was devised. The Type-1 instruments had at least shown that evaporation could be measured in below-freezing weather and that its amount was not inconsiderable.

The Type 2 wick evaporimeter, figure 1, embodied the idea of the "inner cell," corresponding in a rough mechanical way to the intercellular spaces of the leaf which the vapor of transpiration must first enter, or, we may say, in which the vaporizing process really occurs, almost free from outside air influences. The tank was of the same size as in Type 1, namely, 5 inches in diameter, and of about a liter capacity, heavily constructed, and with drain cock. On this was built a lighter superstructure of the same diameter, 3 inches high, and over this a low conical cover was laid, having a flange which fitted closely on the superstructure and was held to it by set-screws. At the peak of the cone a circular opening was made with a diameter of about 3.5 cms., or an area of almost exactly 10 sq. cms., for the admission of sunlight. In the "shade" instrument there was the same opening, but it was surmounted by a secondary conical cover 1 cm. above the first, and slightly more extensive than the opening.

Within the superstructure was a cylinder 3 inches in diameter, its open top terminating at the same level as the main walls; its lower end terminating in a wide-mouth funnel which opened just above the water level in the tank, or at the water level with the tank filled. On the inside of this cylinder was placed a cylindrical,

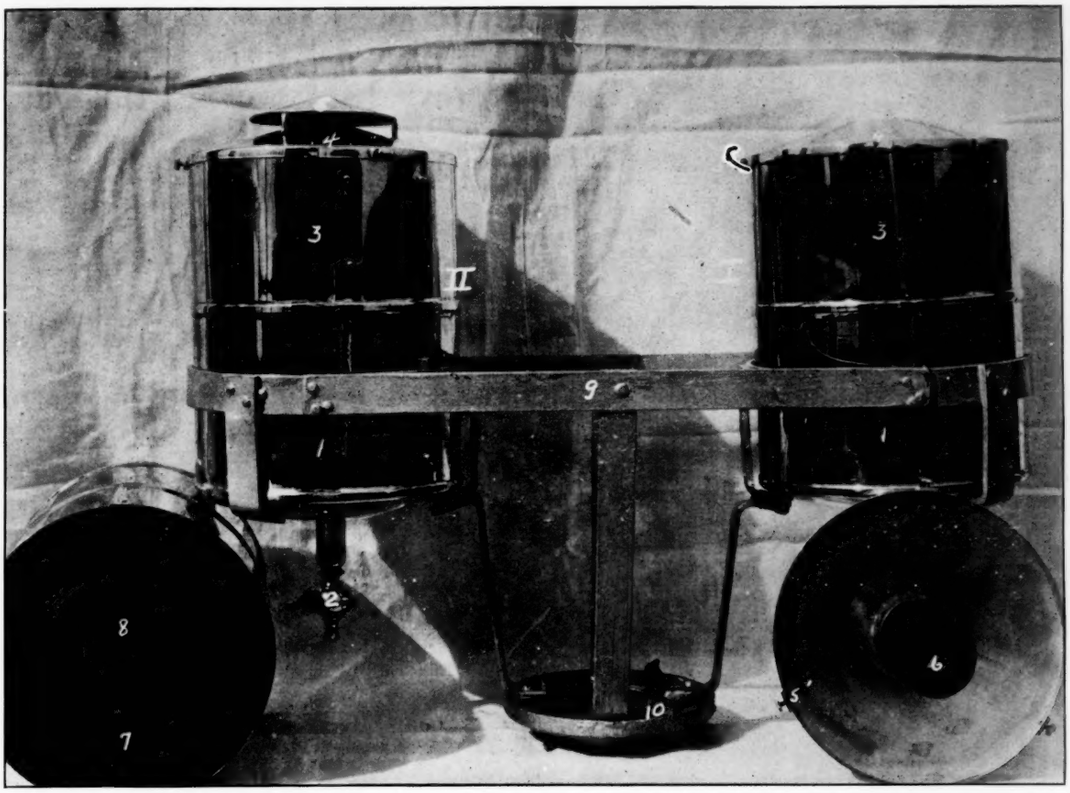

FIG. 1.—Type 2 Inner-cell Evaporimeter. I "Sun" and II "Shade" instrument, in appropriate basket for their support. (1) Tank, (2) Drain-cock, (3) Superstructure, (4) Cover, (5) Set screw to hold cover, (6) Opening for light and ventilation, and hood to shade opening on "shade" instrument, (7) Inner cylinder, (8) Funnel through which wick reaches into tank, (9) Basket, (10) Flange by which basket is secured to end of pipe or fastened to plank set in ground.

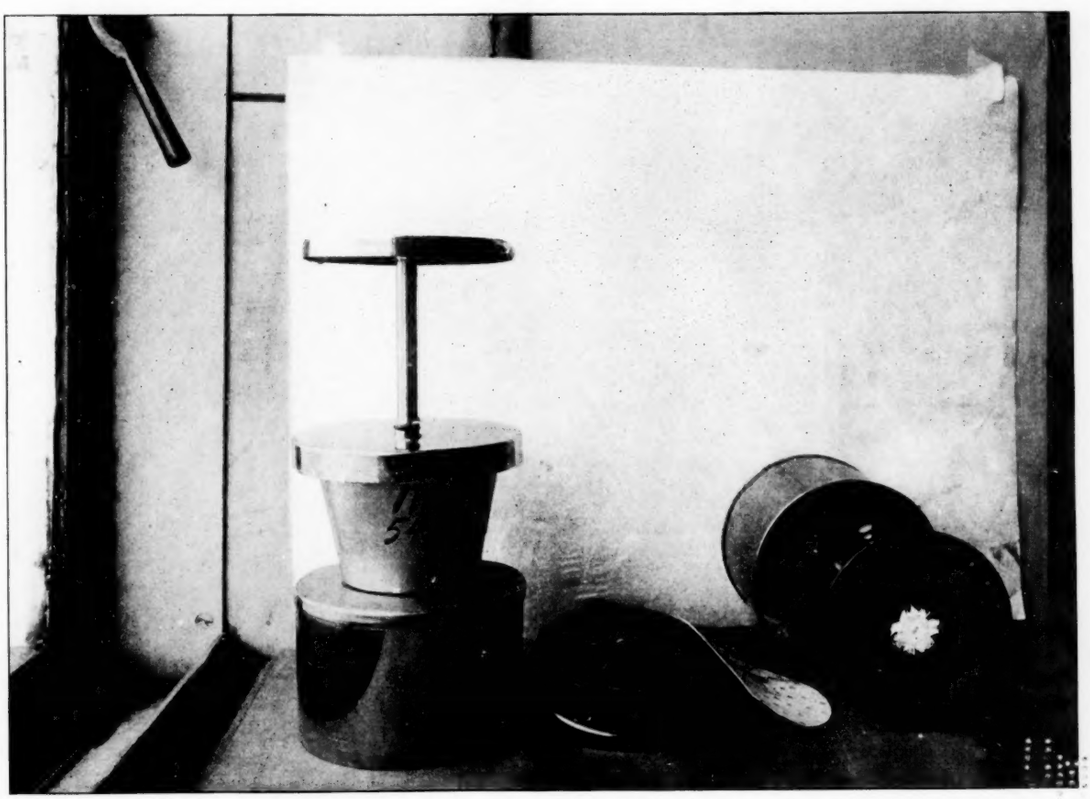

FIG. 2.—Type 4 Evaporimeter. On the left, complete instrument resting on its inverted base or shell, as for weighing. On right, instrument with disk exposed, showing perforations and end of stem wick. In center, blackened cover, and disk wick, which is stained, after 6 months' use.

linen wick, held in position by having its top edge turned over the rim of the metal cylinder and covered by a clamp band. The wick was long enough to reach down into the water, and to practically close the metal funnel. There was thus exposed on the interior of the second wall of the instrument a moist surface calculated to be about 189 square centimeters, practically removed from any heat which the walls of the instrument might absorb, and receiving its heat primarily through a horizontal opening of 10 sq. cms. area, which would, of course, illuminate different portions of the wick at different hours.

Two difficulties were experienced in the operation of this instrument. First, it was not found, as had been hoped, that the rain or snow taken in through the 10 cm. opening could be accounted for by measuring the depth of precipitation in an ordinary gage. The amount "shipped" was occasionally more, but usually less than the area of the opening would imply, and while usually a small factor as compared with the evaporation from 189 cms. of wick, could never properly be ignored. Secondly, the hood used to exclude sunlight from the opening of the "shade" instrument undoubtedly interfered with air movement and diffusion as shown by comparison of the instruments at night. For these reasons the comparisons of the two kinds of instruments were often vitiated, and as correction can not be made for precipitation absorbed by the "sun" instruments, only the records of the "shade" have been used for any purpose.

Type 3 was very similar to Type 2. To make sun and shade instruments equal as to air circulation, however, the air was admitted between the top edge of the outer shell and the flange of the conical cover, the latter being raised about 1 centimeter. The wick was placed on the *outside* of the interior cylinder, while the inner surface of the latter was blackened to absorb such sunlight as should reach it. It was expected that the heat would be conducted through the metal cylinder to the wick on its outer surface. This it did not do satisfactorily. To account for precipitation, which, as in Type 2 might enter the "sun" but not the "shade" instrument, the inner cylinder was sealed at its lower end, the plan being to withdraw accumulated water before weighing for water-loss. This instrument was only tried long enough to show that the practical difficulties had been overcome, inconvenience had been created, and the technical features of the Type 2 had been practically destroyed, as the sensitiveness to sunlight was much weakened, and the sensitiveness to air movement greatly increased.

Type 4 was evolved at almost the same time as Type 3 and was placed in service at a number of stations in January, 1917. (See figures 2 and 3.)

The essential features are:

1. A light, seamless copper tank, slightly larger at the top than bottom, to facilitate spinning and also, possibly, to somewhat relieve ice pressure on the bottom of the tank, it having been noted that after a vessel has been somewhat rounded on its bottom by ice pressure, further freezing within it does not cause appreciable change of shape. The capacity of the tank is about 450 cc.

2. An outer, polished shell, somewhat larger than the tank, to protect the tank from insolation, to keep it clean, to furnish a larger base for the instrument, and to be removed in weighing.

3. A hollow stem of strong brass tubing, opening into the upper portion of the tank at its center, and surmounted by a horizontal metal disk about 10 cms. above the tank. In this stem is placed a linen wick, made by rolling a piece of the heaviest damask about 7 inches square, the threads being drawn on one edge so that when rolled the upper end may be flattened out into a rosette.

4. The horizontal metal disk has a diameter of 11.27 cms. (4.44 inches) giving it an area of 100 square centimeters. It is of 16-gauge brass, or approximately one-sixteenth inch thick. It is perforated by 64 drill holes made with one-eighth-inch drill, giving a total area of openings of about 5 square centimeters. The stem wick projects slightly above the level of this disk, the end of the wick being flattened out, in a rosette, as aforesaid.

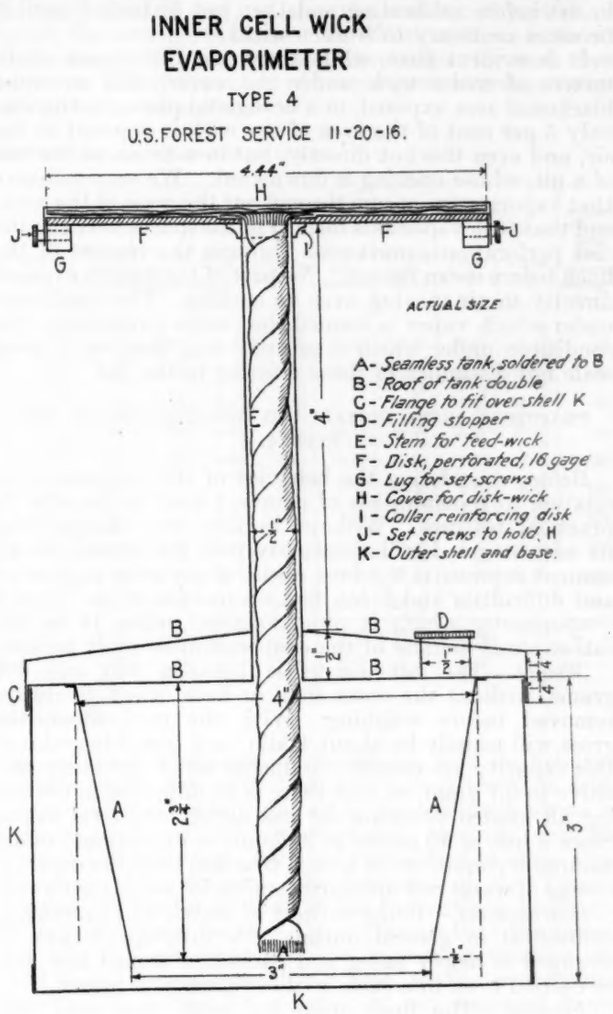

FIG. 3.

The disk wick, a flat piece of similar heavy damask, is then laid on the rosette. The disk wick should be cut about 4.2 inches in diameter to cover the disk fully when moist.

5. The cover is flat, barely larger than the disk, and having a 1 cm. flange which covers the edge of the disk when in position. In this flange are two notches or slits, engaging sets screws on the edge of the disk. Holding the cover down firmly against the wick, the screws are set. The cover, and all exterior surfaces of the instrument are nickeled and polished. The polished cover absorbs very little of the energy of sunlight, while a coating of lampblack and turpentine gives it high

absorbing qualities. This coating is fairly durable under weather action, yet can be removed without affecting the nickel coating. Mixing the lampblack with turpentine gives a fair binding quality without any luster such as would result from ordinary paint mixtures.

Once the cover has been set against the wick, it should not be removed unless absolutely necessary, since any change in its position will affect the degree of contact between the cover and the wick, and hence the extent to which the heat absorbed by the cover is conducted to the wick and is effective in evaporation. The cover should be set before calibrating and then not disturbed until it becomes necessary to freshen wicks.

It is evident that, while there are 100 square centimeters of moist wick under the cover, and an equal blackened area exposed, in a horizontal plane, to the sun, only 5 per cent of the area of the wick is exposed to the air, and even this not directly, but in a recess at the end of a pit, whose opening is downward. We may conceive that vaporization occurs throughout the mass of the wick, and that such vapor as is formed in the spaces between the disk perforations, must pass through the meshes of the linen before it can escape. No part of the wick is exposed directly to air moving over its surface. The conditions under which vapor is formed, but more particularly the conditions under which it escapes, are, then, on a gross scale not dissimilar to those existing in the leaf.

PRACTICAL DIFFICULTIES AND ADVANTAGES OF THE TYPE 4.

Before considering the behavior of this instrument in relation to transpiration of plants, I wish to describe its practical features. Without in any way exaggerating its advantages, I will simply say that the present development represents the best result of my own experience and difficulties and I can find no feature of the Type 4 evaporimeter which is objectionable, unless it be the rather small volume of the evaporation in short periods.

Weight.—The net weight is between 500 and 600 grams, without the outer shell or base, which is always removed before weighing. With the tank filled, the gross will usually be about 1 kilo, and portable scales of this capacity are readily obtainable which are fairly sensitive to 0.1 gram, so that there is no difficulty in obtaining all needed precision for measuring long-term losses. Since a loss of 40 grams in 24 hours is exceptional under mountain conditions, it is seen that less than the capacity charge of water will ordinarily suffice for weekly intervals.

Compactness.—Being entirely of metal, and practically cylindrical in general outline, the instrument may be wrapped in heavy paper and packed in almost any box, or carried even in a sack, without danger of injury.

Feeding.—The linen used for both stem and disk wicks has strong capillary properties, and if clean will readily moisten to the extreme edges of the wick within an hour or two of the time of filling the tank. The capacity of the wicks to supply rapid evaporation losses has never been seriously taxed. Of some 30 instruments in use during part or all of 18 months, only 2 have shown any inclination to overfeed and drip. The exact cause of this could not be traced, but it was probably due to stem wicks being too tight, causing water to be forced up in them under air pressure, as the tanks warmed in the middle of the day. No dripping as a result of wetting by fog or rain has ever been noted. One or two instruments have at times absorbed rain water, which flowed over the edge of the cover and entered around the set screws. This is not likely to happen, however, if the notches for the set screws are properly cut, and can be prevented by using rubber gaskets below the heads of the screws.

SOILING AND REPLACEMENT OF WICKS.

The instruments have been used in a remarkably dust-free region, and hence any soiling of the exposed portion of the disk wicks is practically unknown. After six months' use with distilled water, however, both stem and disk wicks, but especially the latter, are likely to be considerably stained with oxides of copper, and their removal, or at least a thorough washing, is desirable, since, of course, the greatest accumulation of such material will be in the small sections exposed to the air. Nothing but distilled water may be used, since even the solutes in filtered water would immediately cause accumulations at the evaporating points. In a region where there is considerable dust, undoubtedly much shorter life of the wicks is to be expected, if good results are to be had. The position of the openings on the underside of the disk, however, reduces this aggravation to a minimum. As with porous clay atmometers, the real danger with proper handling is to be looked for in the action of water on the instrument itself. One must not wait until the capillary properties of the linen are destroyed, since *any appreciable quantity of soluble matter in the water to be evaporated will affect the evaporation rate.*

Calibration.—No effort was made to calibrate the several instruments in use until the season of 1918, so that the possibilities in this line have not been fully tested. Testing ordinarily for periods of a week, however, the 30 instruments have shown ratios to the standard ranging from 0.785 to 1.230. The great majority, however, fall between 0.900 and 1.000, the standard, taken arbitrarily from among the first instruments made, losing a little more water than the average of the others. Successive calibrations on the same instrument usually give very consistent results, but it is possible, by changing wicks, by resetting covers in somewhat different positions, and by altering the environmental conditions for calibration, to obtain quite variable results. In other words, no two instruments respond exactly the same to changes in environment, though doubtless their responses are more similar than would be the responses of an instrument and a plant. Of all the factors causing variation in and between instruments, the position and contact of the cover with the wick seem by all odds the most important.

It is evident from the variations between instruments that none should be used without standardizing, although, however carefully this is done, it will not cover all possible field conditions. After standardizing great care should be used not to disturb the relation between the absorbing cover and the wick.

BEHAVIOR OF INSTRUMENTS IN RELATION TO TRANSPIRATION OF CONIFEROUS TREES.

As has been stated, some of the ideas as to the qualities which an atmometer should possess were gained through Burns's results in comparing the transpiration of pine seedlings with evaporation from black and white porous cups. The writer has not been particularly interested in, nor has he had opportunity to consider the transpiration behavior of herbaceous plants. During 1917, however, the daily transpiration losses of 12 small coniferous trees were determined over a period of

more than 5 months, and during most of this time several types of atmometers were operated on the same table with the plants. In all there are 116 periods, mainly of 24 hours each, in which some or all of the atmometers may be compared with the plants.

Atmometer ratios for different kinds of days.—The 116 periods have been divided into days of ten classes; first, according to the duration of sunlight, and secondarily according to the estimated amount of air movement. It should be understood that with the exception of one day all of the exposures were made in the greenhouse on a table which during a part of the time was moving steadily and with sufficient speed to create some circulation about the plants. During a larger part of the time, however, it was moved only periodically. Part of the time the greenhouse was closed quite tightly, and at other times ventilators were opened enough to produce considerable draft. The periods divide themselves roughly then into (1) those with no ventilation, (2) those with only the circulation caused by rotation of the table, and (3) those with an appreciable amount of natural air circulation. Group 2 is sufficiently represented to be considered separately only for the larger group of days having 201–500 minutes of sunshine. In addition, it is necessary to consider the single day out-of-doors in a class by itself, as the amount of air movement was out of all proportion to that in the greenhouse.

Table 1 shows for each type of atmometer the average ratio of its loss to the total transpiration of the 12 plants for each kind of day, as also the number of periods on which the average is based. In addition, there is shown the average daily amount of transpiration for each class of days. All of the ratios of evaporation to transpiration are given as percentages.

TABLE 1.—*Average ratios of evaporation to transpiration for different kinds of days.*

Character of exposure.			Instrument.													Amount of transpiration (average per day).
Sunshine.	Ventilation.		No. 2, sun.	No. 3, shade.	No. 3, sun.	No. 4, shade.	No. 4, sun.	No. 4, sun, 1-gauze.	No. 4, sun, 2-gauze.	No. 4, sun, 3-gauze.	No. 4, glass.	Livingston white.	Livingston black.	Piche shade.	Piche sun.	
None	None	Number days	14	4	4	3	9	8	6	6	8	9	9	4	8	9
		Ratio	2.67	13.16	13.50	6.15	7.29	6.45	5.79	6.32	7.92	27.94	27.92	22.06	25.82	49.8
	Ventilation	Number days	5	5	5	3	8	8	5	5	7	7	8	5	8	9
		Ratio	3.29	13.80	15.00	6.27	7.52	6.56	6.35	7.38	8.31	33.66	32.76	23.76	28.26	56.7
1–200 minutes	None	Number days	6	6	6	2	8	7	6	6	8	7	8	6	8	9
		Ratio	1.74	6.16	6.24	3.98	4.23	3.58	3.19	3.67	4.19	13.97	14.87	11.28	12.27	90.1
	Ventilation	Number days	13	13	13	5	14	14	7	7	13	13	12	13	14	20
		Ratio	2.25	7.94	8.64	4.15	4.71	4.06	3.93	4.51	5.04	18.18	18.39	13.87	15.22	66.8
201–500 minutes	None	Number days	6	6	6	0	9	9	9	9	9	9	9	6	9	10
		Ratio	1.54	6.29	6.20	.....	4.71	4.07	3.56	4.04	4.45	10.59	11.33	7.94	9.84	160.0
	Rotation	Number days	2	2	2	2	2	2	0	0	2	2	2	2	1	2
		Ratio	2.24	5.06	5.74	2.91	3.88	3.22	.....	.....	3.76	7.13	9.35	4.84	5.51	141.8
	Ventilation	Number days	37	37	37	27	46	45	19	19	32	44	46	36	45	48
		Ratio	2.76	7.82	8.86	3.49	4.50	3.86	3.38	3.94	4.24	12.38	13.82	8.24	10.48	170.5
Over 500 minutes	None	Number days	6	6	6	5	6	5	1	1	1	6	6	6	6	6
		Ratio	3.57	7.98	9.22	5.54	6.66	6.09	3.54	3.59	3.78	10.96	12.62	8.57	9.44	180.8
	Ventilation	Number days	13	13	13	12	13	10	1	1	5	11	13	13	12	13
		Ratio	4.28	9.78	10.66	4.60	6.13	5.37	3.77	3.72	5.48	13.22	15.26	10.27	11.30	205.8
	Wind	Number days	1	1	1	1	1	1	1	1	1	1	1	.....	.....	1
		Ratio	10.13	24.20	26.67	9.06	5.45	6.30	9.06	7.79	10.60	20.72	26.00	14.45	.....	228.5
Average ratio			3.45	10.22	11.07	5.13	5.51	4.96	[1] 4.73	[1] 5.00	5.78	16.88	18.23	12.53	[1] 14.24	.....
Sum of variations			15.19	41.01	43.89	13.02	11.14	11.88	13.02	13.02	19.01	66.01	64.28	48.06	53.18	.....
Average variation			1.52	4.10	4.39	1.45	1.11	1.19	1.45	1.45	1.90	6.60	6.43	4.81	5.91	.....
Per cent of variation			44.0	40.1	39.6	28.3	20.2	24.0	30.7	29.0	32.9	39.1	35.1	38.4	41.5	.....

[1] Not complete for all classes of days.

REMARKS ON TABLE 1.

1. In the cases of Type 3 Inner-cell, Type 4, and Livingston porous-cup, the variations from the average ratio to transpiration are less for the so-called "sun" instruments than for the corresponding type which absorbs sunlight less completely. This indicates plainly the need for complete sunlight absorption to obtain a response similar to that given by the plants. The failure of the Piche to show this relation is doubtless due to the fact that the fully-insolated paper often becomes dry at the edges or otherwise fails to evaporate to capacity under strong sunlight.

2. In the Type 3 Inner-cell, and in the Livingston porous-cup, and Piche instruments, both "sun" and "shade" instruments show very high ratios when sunlight is deficient, owing to the free exposure of the evaporating surfaces to moving air. In all types the response to a small amount of sunlight is less than with plants.

3. Essentially the same instruments show decided increases in ratio with increase in the amount of ventilation in each sunshine group. All of the Type 4 instruments show this increase less markedly. The plain Type 4 "sun," without gauze, is especially steady under the influence of increased circulation, and its behavior on the single day with "wind" (out-of-doors) is truly remarkable. It is not desired to lay too much stress on this single record. It is to be noted, however, that the Type 4 1-gauze "sun" behaved similarly, the other Type 4's, being less similar. The behavior of the Type 4 "shade" is similar to that of the free-surface Piche and Livingston instruments. This indicates that the principal effect of air movement, in increasing evaporation, may arise through supplying heat to the evaporating surface rather than by assisting in any material degree in accelerating diffusion of the vapor molecules, for in the latter respect the influence on the "sun" and "shade" instruments of Type 4 should have been the same. We then see that on days with a large amount of sunshine the blackened Type 4 is not accelerated by wind, more than are the plants, because both may be slightly warmer, at least superficially, than the air. Air movement may, therefore, carry away heat, almost as largely as it brings heat.

4. All things considered, the Type 4 "sun" instrument behaves, under a variety of conditions, most like the plants, and the others show wider variation about in proportion to the degree in which they expose the evaporating surface to moving air and fail to absorb fully

the heat of sunlight. The Type 2 "sun" is an exception in that it is not responsive to small amounts either of sunlight or of air movement. Its actual losses are very small, in proportion to the wick area exposed, indicating that they are too largely controlled by the small opening at the top of the instrument, which being considerably removed from the evaporating surface, creates altogether too much of a dead-air space within the chamber.

The Type 4 with various layers of gauze, and that one in which glass was substituted for the metal cover, are not superior to the original conception. It should be said that the layers of fine, brass gauze, of the same size as the disk wicks, were placed beneath the wicks in the hope of increasing the total evaporation by facilitating the movement of vapor toward the "stomatal" openings. Instead, they have evidently had the effect of creating a larger chamber for vapor storage, a dead-air space as in the Type 2, and have removed the wick further from the influence of the disk, which might at times be a source of heat.

It may be said to overcome objections, that if we should eliminate from consideration the single day with "wind" whose influence on the final result for Type 4 "sun" is negligible, this instrument would still stand superior to the others. Its percentage of average variation would then be 22.3, as against 34.5 per cent, for example, for the blackened Livingston cup.

INSTRUMENTAL VARIATION FOR SIMILAR DAYS.

Does any type of instrument show a constant relation to transpiration if the environmental conditions remain constant?

This question could undoubtedly be answered in the affirmative if we were speaking of successive periods alike in every respect, and not in any degree taxing the capacities of either plants or instruments, or producing progressive changes in them.

With the present data we can only compare days having a general resemblance. It is to be noted that days with 201–500 minutes of sunshine and with some ventilation are most numerous as shown by Table 1. We shall, therefore, analyze this group. In Table 2 the instruments are compared for days of this class.

TABLE 2.—*Variability of instruments for days of similar sunshine and air movement.*

Datum.	Type of instrument.												
	No. 2 sun.	No. 3 shade.	No. 3 sun.	No. 4 shade.	No. 4 sun.	No. 4 sun, 1-gauze.	No. 4 sun, 2-gauze.	No. 4 sun, 3-gauze.	No. 4 glass.	Livingston, white.	Livingston, black.	Piche shade.	Piche sun.
Average ratio to transpiration (per cent)	2.76	7.82	8.86	3.49	4.50	3.86	3.38	3.94	4.24	12.38	13.82	8.24	10.48
Number of periods	[1] 37	[1] 37	[1] 37	[1] 27	46	45	[2] 19	[2] 19	[2] 32	44	46	[1] 36	45
Sum of variations (per cent)	20.42	49.65	53.57	17.75	34.16	31.02	10.56	11.45	21.98	132.31	122.92	56.27	114.87
Average variation from average ratio (per cent)	.552	1.341	1.447	.658	.743	.690	.556	.603	.687	3.008	2.671	1.563	2.551
Per cent of average variation	20	17.2	16.3	18.8	16.5	17.9	16.4	15.3	16.2	24.3	19.3	19	24.3

[1] Deficient at end of season.

[2] Deficient at beginning of season.

The No. 4 "sun" instrument is seen here to be among the least fluctuating of the instruments with environmental conditions not going to any great extremes either as regards sunlight or air movement. The most variable, in order, are the Piche "sun" and white porous-cup, No. 2 "sun," black porous-cup, Piche "shade" and No. 4 "shade."

No. 3 "sun" and Nos. 4 with 2-gauze, 3-gauze, and glass variations, show themselves as consistent, or more consistent in relation to transpiration than the regular No. 4 "sun." These, however, are all deficient as to time; that is, they did not experience the entire range of conditions to which the others were subjected. The full significance of this will be seen in the next paragraph. If we compare Type 4 "sun" with Type 4 3-gauze, which shows the least variation, in the period in which the latter was operated, the variation is only 14.6 per cent for Type 4 "sun." It only seems safe to say that the Type 4 group, as a whole, adheres most closely to transpiration rates, and this in spite of the fact that its actual evaporation losses are small and the variation due to inaccuracy in weighing should be a larger factor.

The variations for days of this general class, ranging from 16 to 24 per cent, are still large and still leave open the question whether under uniform environmental conditions plants and evaporimeters may accord, which is really a question of whether the plants themselves are governed closely by exterior physical conditions or exercise some control in the vitalistic sense.

For better data on this point we may refer to the period November 2–8, inclusive, when the weather conditions were very uniform, the greenhouse was constantly ventilated, and there was no artificial shading. The duration of sunlight in these seven days varied from 376 to 477 minutes per day, the morning vapor pressures from 0.121 to 0.189 inches, and the daily transpiration totals from 151.4 grams to 127.9 grams. As these are all moderate amounts, we can not conceive of the plants being seriously taxed or suffering any cumulative changes. Under these conditions the following mean variations of the evaporimeters are noted, which are really quite reassuring as to the possibilities of atmometry.

	Per cent.
No. 4 "sun"	4.2
No. 4 "sun," 1-gauze	6.3
No. 4 "sun," 2-gauze	5.9
No. 4 "sun," 3-gauze	7.5
No. 4 glass	7.8
Livingston, white	8.7
Livingston, black	4.6
Piche "sun"	7.1

Seasonal ratios to transpiration.—It has been brought out in the study of the transpiration of the trees that toward the end of the season the total transpiration decreased slightly in proportion to the atmospheric stresses. For a given set of conditions there was, at the close, somewhat less transpiration than for similar conditions in the early part of the season. This change was thought to be due to the aging and thickening of leaf epidermis as the season advanced and to increased solutes in the cell sap. The marked change, however, was restricted to one specimen of Douglas fir, apparently in an unhealthy state.

Such being the case, we should expect the ratios of instrumental evaporation to transpiration to increase toward the end of the season. Table 3 shows what actually happened. Only the days with 201–500 minutes of sunshine and with some ventilation are considered.

TABLE 3.—*Ratios of evaporation to transpiration at different times in the season.*

Datum.	Type of instrument.				
	No. 4, sun.	No. 4, sun, 1-gauze.	Livingston.		Piche, sun.
			White.	Black.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Average ratio for all days of this class	4.50	3.86	12.38	13.82	10.48
First 10 days, June 8–27	5.22	4.45	12.42	14.04	11.16
Middle 10 days, Aug. 1–28	3.85	3.14	[1] 10.38	12.48	8.46
Last 10 days, Oct. 9–Nov. 8	4.88	4.24	17.64	18.30	14.73

[1] Only 9 days.

For all types of atmometers having this complete record the ratio is lowest at midseason.

For the Type 4 "sun" and its counterpart, the evaporation is relatively less at the end of the season.

For the Livingston cup, and the Piche, the evaporation rate is higher at the end of the season. This is what should be expected *if* the transpiration did decline, for the Livingston cups, at least, being spherical, would hardly be affected by the low elevation of the sun late in the season. The similar performance of the Piche is difficult to explain.

The behavior at midseason is difficult to explain except on the ground of free transpiration in the trees as a whole, which apparently existed. Such vigorous transpiration may possibly be accounted for by the completion of new growth and the lack of concentrated solutions and of thickened cell walls in the leaves.

The behavior of the Type 4 instruments indicates that the horizontal surface exposed to the sun is not all that might be desired for the study of individual plants. It should be stated that this kind of surface was definitely striven for in the view that in forest studies we are not so much concerned with the conditions affecting the individual plants as with, for example, the evaporation per unit of ground area. This view, however, is seen to be untenable in considering the factors which control the fate of the seedling and in large measure the ecological distribution of the species, for the individual seedling is a unit of itself, and half a million other seedlings on the same acre would hardly affect its response to evaporation stimuli.

It is seen, however, that the Type 4 "accidentally" takes care, pretty well, of the decreased tendency toward transpiration after the apex of the season is passed.

Daily periodic evaporation and transpiration.—As a further check of the various types of atmometers against the behavior of plants, both were measured on a bi-hourly basis for one day, October 27, 1917. The day was clear after 9 a. m. and before 4 p. m., showing 436 minutes of sunshine out of a possible of 634. The greenhouse was kept closed, so that there was no air circulation except that created by the movement of the table. Artificial heat was used in the latter part of the day and at night, so that the temperatures were very high and tended to tax the transpiration capacity of the trees.

Before considering the relation of the evaporation from instruments to that from the trees, it will be well to note the behavior of the trees with relation to the environmental conditions. This is made possible by frequent observations on humidity and by frequent checks of the black-bulb temperatures recorded by the thermograph. As has been discussed in another paper (I) the saturation deficit expressed by the difference between actual vapor pressure and saturation pressure corresponding to the "sun" or black-bulb temperature, in the absence of appreciable air circulation would appear to control most directly the rate of diffusion of the vapor from plants. In the present case, the relations would not be materially changed if we considered the plant temperatures reduced by an amount, for example, equal to the wet-bulb depression, which would be about the only basis for correcting the recorded "sun" temperatures.

The data on which Diagram 1 is based are shown in the following table:

TABLE 4.—*Environmental conditions affecting periodic evaporation on Oct. 27, 1917.*

Datum.	Condition observed at—							Mean for period centering at—					
	7:28 a.	9:28 a.	11:27 a.	1:30 p.	3:28 p.	5:33 p.	7:00 a.	8:30 a.	10:30 a.	12:30 p.	2:30 p.	4:30 p.	12:15 p.
Sun temperature [1]	41.9	62.9	94.5	109.0	99.2	64.8	52.5	49.5	80.0	104.0	106.5	88.0	[3] 63.3
Saturation pressure [2]								.354	1.022	2.160	2.326	1.322	.581
Dry-bulb temperature	41.4	60.9	80.0	90.0	82.0	68.1	53.6						
Wet-bulb temperature	38.4	50.8	60.5	69.3	61.7	53.2	46.8						
Vapor pressure [2]	.206	.282	.360	.528	.379	.282	.263	.244	.321	.444	.454	.330	.272
Saturation deficit								.110	.701	1.716	1.872	0.992	.309

[1] Means for periods computed from thermograph record.
[2] Computed from table for barometric pressure 23 in., as local table does not reach highest temperatures.
[3] Temperature held up after 5:30 p. m. by artificial heat, going as high as 70° F. at 10 p. m.

Diagram 1 (fig. 4) indicates that the rate of transpiration is proportionate to the evaporation stresses, as measured by saturation deficits, until practically through the period ending at 1:30 p. m. Then it falls very rapidly, though the atmospheric stress is even greater in the next period. During the afternoon and night the curve returns at a lower level, apparently approaching its original base at the beginning of the second day.

There are several possible explanations of this diurnal curve:

1. The stomata may close when the highest transpiration rate is attained.

2. The morning transpiration may be in excess of water intake, thus tending to produce a gradually more concentrated solution in the leaves. If this alone were the cause, however, we should not expect such a marked drop in rate for the period 1:30 to 3:30 p. m., and we should expect more rapid recovery to the morning rate, since in the period mentioned the loss was scarcely greater than from 9:30 to 11:30 a. m.

3. The morning transpiration rate may be accelerated by the *rise* in temperature, as discussed in the theoretical phases of the subject. In this instance the highest sun temperature was recorded just about 1 p. m., but there was a secondary rise of about 5° F. an hour later. The greatest sunlight intensity was probably at noon or a little before.

That the sudden decline in transpiration rate soon after noon is not due either to the factor described under (1) or

(2) above may be determined by inference from an examination of the behavior of the different species which comprised the group of 12 trees. In fact, one yellow pine showed a slight increase while the other trees were decreasing. The behavior of the species is shown by diagram 2 (fig. 5). Comparing the loss in the fourth

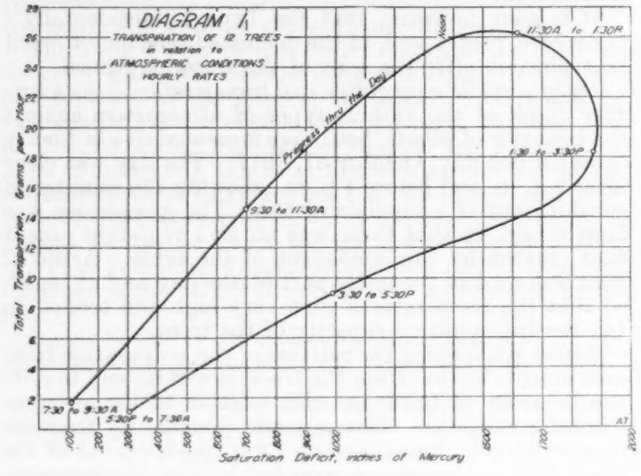

FIG. 4.

with that in the third period, for each species, we obtain the following relations:

Species.	Loss immediately after highest temperature relative to that before the maximum.
Yellow pine	0.972
Bristle-cone	.728
Limber pine	.650
Engelmann spruce	.617
Lodgepole pine	.450
Douglas fir	.387

The behavior of the last two species adequately banishes the idea that reduction of transpiration is due to exhaustion of either the plant water or soil moisture. The species showing the least total loss is most reduced; that showing the greatest most nearly maintains its rate. As between these extremes, we believe the difference to be one primarily dependent on the condition of the trees. The transpiration of lodgepole and Douglas fir, relative to the whole, had been declining for some time prior to this test. We may, therefore, conceive that they were in a state of maturity, represented by thickened walls, dense sap, and possibly closed stomata, such that sunlight penetrated their walls with difficulty, and the vapor formed was forced through the stomata under considerable pressure. With the first decrease in temperature and sunlight intensity, therefore, the internal pressure falling, the vapor escaping is much reduced. In short, if we conceive that the avenues for escape are much restricted, the rate of loss becomes little dependent on the saturation deficit, or differential, but almost wholly on the absolute internal vapor pressure.

With the other four species, all of which appeared to be functioning at this time much the same as in the early part of the season, we may believe that there was much less mechanical restriction upon transpiration. In a rough way, their respective declines after the diurnal maximum of radiation, appear to be related to the density and arrangement of their foliage. The leaves of the yellow pine, forming almost a rosette, are open both to sun and air temperature influences almost as much at one time as another. The compact foliage and erect form of spruce may be such as to induce the maximum of insolation of the foliage with the sun at the zenith. Bristle-cone and limber pines stand in intermediate positions in this respect.

It is believed, then, that the general decline in transpiration rates before the maximum atmospheric stresses appear to occur is primarily a question of insolation of the foliage and of resistance to vapor diffusion due to a fixed condition in the plants, such that the internal vapor pressures are in a sense cumulative, and with any decrease in the leaf temperatures, immediately following lessened insolation, there is a decided tendency toward condensation and toward curtailment of diffusion, even if saturation deficits as measured by temperatures outside the plants, remain high.

The correct analysis of the situation is important in this discussion; for if the above is true, we may hope to simulate the plant condition in a mechanical contrivance. If the decline is due to stomatal movement or to increasing sap density, primarily, we can not hope to duplicate the conditions in any automatic instrument.

That the insolation received, and the actual temperature and absolute vapor pressure at the point of vaporization control more largely than the saturation deficit, is shown by the behavior of all the atmometers which absorb sunlight sufficiently to reflect a "sun" temperature of their own.

Table 5 shows the periodic data for instruments and trees. Diagram 3 (fig. 6) shows the same data on a basis of hourly rates.

TABLE 5.—*Periodic evaporation Oct. 27–28, 1917.*

Period.	Type of atmometer.									Total all instruments.	Total transpiration.
	No. 4 sun.	No. 4 1-gauze.	No. 4 2-gauze.	No. 4 3-gauze.	No. 4 glass.	Livingston, white.	Livingston, black.	Piche sun No. 1.	Piche sun No. 2.		
										Grams.	*Grams.*
7:30–9:30 a	0.20	0.10	0.05	0.25	0.15	0.65	0.60	0.50	0.50	3.00	3.5
9:30–11:30 a	1.20	1.20	0.85	0.85	1.05	1.50	2.25	1.90	1.80	12.60	29.0
11:30 a.–1:30 p	2.95	2.10	2.05	2.60	2.15	3.15	5.60	5.60	5.00	31.20	52.4
1:30–3:30 p	2.25	1.65	1.40	1.40	1.70	4.15	4.50	3.80	3.90	24.75	36.6
3:30–5:30 p	0.85	0.9	0.8	0.85	1.0	2.9	2.9	2.7	2.9	15.80	17.8
5:30 p–7:00 a	2.80	2.45	2.30	2.70	3.20	11.60	12.30	9.50	9.20	56.00	14.5

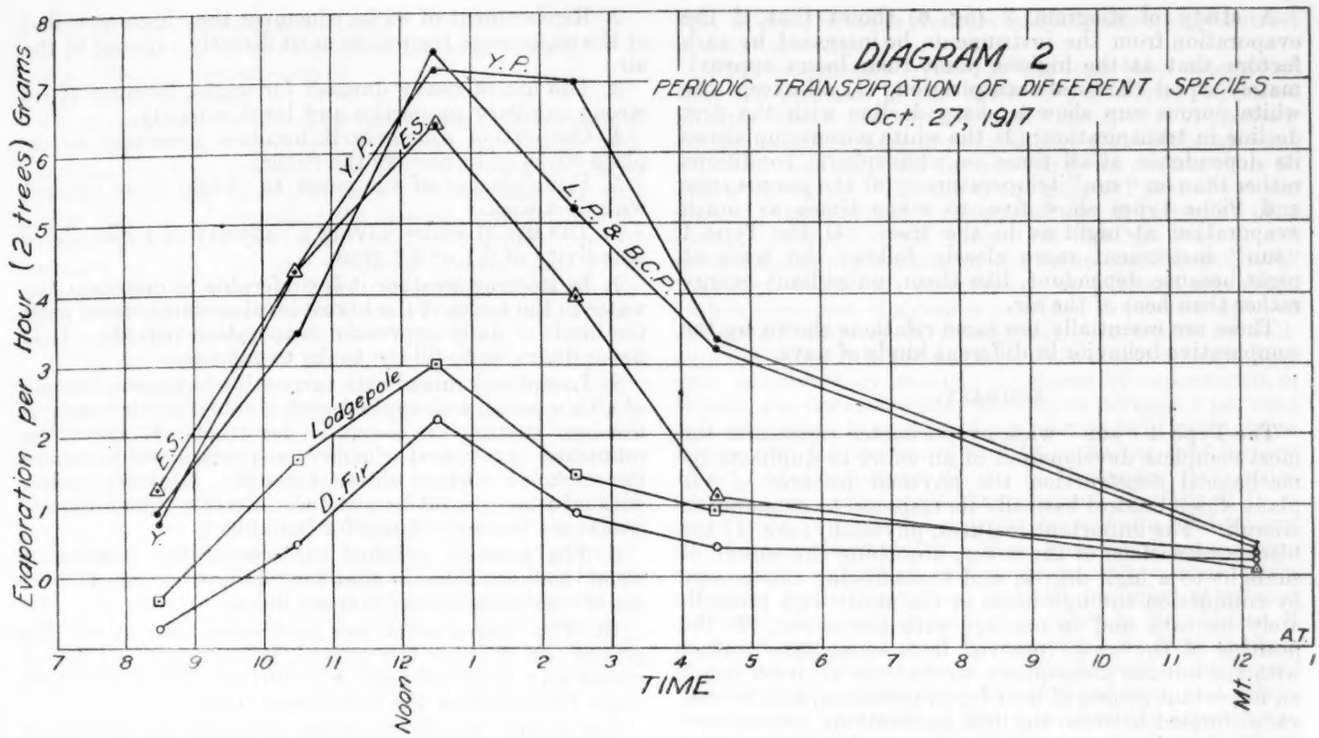
DIAGRAM 2
PERIODIC TRANSPIRATION OF DIFFERENT SPECIES
Oct. 27, 1917
Evaporation per Hour (2 trees) Grams
Y.P.
E.S.
L.P. & B.C.P.
Lodgepole
D. Fir
TIME
Noon
Mt.
AT.

FIG. 5.

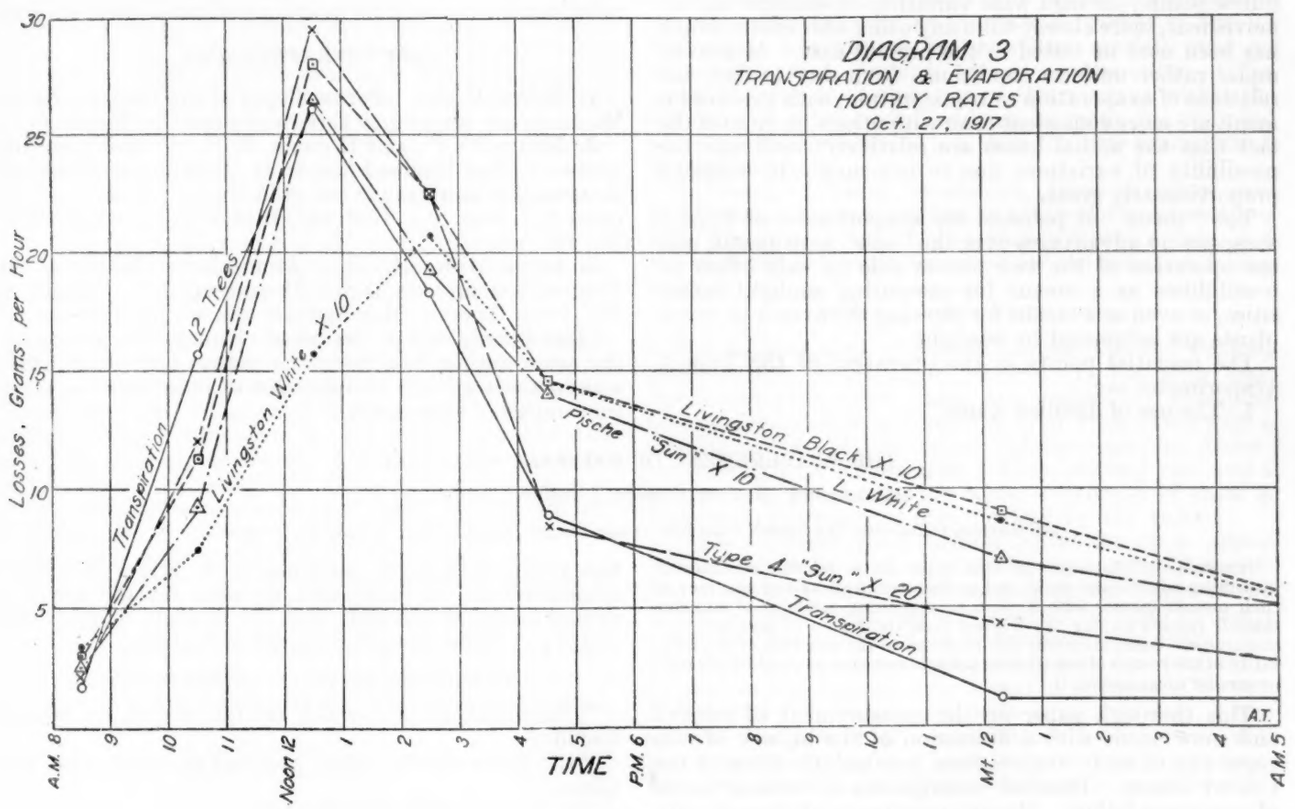
DIAGRAM 3
TRANSPIRATION & EVAPORATION
HOURLY RATES
Oct. 27, 1917
Losses, Grams per Hour
Transpiration 12 Trees
Livingston White X 10
Livingston Black X 10
Pische
Sun X 10
L. White
Type 4 "Sun" X 20
Transpiration
TIME
A.M. 8
Noon 12
P.M. 6
Mt. 12
A.M. 5
AT.

FIG. 6.

A study of diagram 3 (fig. 6) shows that if the evaporation from the instruments be increased by such factors that at the highest point their losses approximately equal the total transpiration, (1) all except the white porous cup show a sharp decline with the first decline in transpiration; (2) the white porous cup shows its dependence at all times on atmospheric conditions rather than on "sun" temperatures; (3) the porous cups and Piche types show five to seven times as much evaporation at night as do the trees; (4) the Type 4 "sun" instrument more closely follows the trees at night because dependent, like them, on radiant energy rather than heat of the air.

These are essentially the same relations shown by the comparative behavior in different kinds of days.

SUMMARY.

The Type 4 "sun" wick evaporimeter represents the most complete development of an effort to duplicate by mechanical construction the physical features of the plant which control basically its response to evaporation stimuli. The important features, physically, are (1) the blackened surface of the cover, absorbing the energy of sunlight to a high degree, and transmitting this energy by conduction through brass to the moist wick immediately beneath and in contact with the cover; (2) the position of the wick, removed from immediate contact with the outside atmosphere, so that the air itself is not an important source of heat for evaporation, and so that vapor formed between the disk perforations, corresponding to stomata, does not diffuse too readily to the outer atmosphere.

These features permit the type 4 wick evaporimeter to follow plants, through wide variations in sunlight and air movement, more closely than any other atmometer which has been used or tested in the present case. Moreover, under rather uniform conditions, from day to day, the relations of evaporation to transpiration, with this instrument, are more consistent than with others, in spite of the fact that the actual losses are relatively small and the possibility of variations due to inaccuracy in weighing proportionately great.

The "shade" or polished-top evaporimeter of Type 4 possesses no advantages over the "sun" instrument, and the operation of the two phases side by side offers no possibilities as a means for measuring sunlight intensities, or even as a means for showing the extent to which plants are influenced by sunlight.

The essential points in the operation of the Type 4 evaporimeter are:

1. The use of distilled water.

2. Replacement of wicks whenever they become soiled at the edges or at the points most directly exposed to the air.

3. The use of heavy damask for wicks, because of its strong capillary properties and large capacity.

4. Calibration whenever it becomes necessary to replace wicks or to remove the cover.

5. Firm placing of the cover to obtain close contact with disk wick.

6. The use of scales having a capacity of 1 kilo and a sensitivity of 0.1 or 0.2 gram.

7. In freezing weather it is preferable to maintain the water in the tanks at the lowest level commensurate with the needs of daily or weekly evaporation periods. It is never desirable to fill the tanks to capacity.

8. Lampblack mixed with turpentine to the consistency of a thin paste, and applied with a camel's-hair brush, is the best coating for covers so far tried. It should be retouched or replaced whenever any considerable area of the nickeled surface shows through. Ordinary paint, with a luster, should be avoided. Certain "dead-black" paints are fair substitutes for lampblack.

9. The exterior polished surfaces of the instrument should be kept clean so that they do not become absorbers of insolation in any marked degree.

10. The instruments are preferably placed on the ground, or, if above the ground, in baskets which do not create any artificial reflecting surfaces below the disk, other than those of the instrument itself.

The present development has produced an instrument which is eminently practical in addition to integrating solar and atmospheric conditions in much the same way as does the plant. No new difficulties are encountered in attempting to use it for year-long climatological studies.

LIST OF REFERENCES.

1. BATES, C. G. "Forest Types of the Central Rocky Mountains in relation to Environmental Conditions."

2. BURNS, G. P., and HOOPER, F. P. "Studies in Tolerance of New England Trees: II. Relation of Shade to Evaporation and Transpiration in Nursery Beds." (Vermont Agr. Exp. Sta., Bull. 181, 1914, Forest Service Publ. No. 15.)

3. LIVINGSTON, B. E. "Atmospheric Influence on Evaporation and its Direct Measurement." (MONTHLY WEATHER REVIEW, March, 1915, vol. 43, pp. 126–131.)

(This is only one of the latest of numerous papers by the same author describing the porous cup atmometer, and contains a fairly complete list of other references on the subject of atmometry.)

THE MEASUREMENT OF RAINFALL AND SNOW.

By ROBERT E. HORTON, Consulting Engineer, Albany, N. Y.

[Abstract from Journal of the New England Water Works Association, 1919, vol. 33, no. 1, pp. 14–71, 21 figs., 12 tables.]

SYNOPSIS.—"The object of this paper is to describe methods of measuring rainfall and snow, and to discuss the errors and accuracy of such measurements, with a view to suggesting methods of securing rainfall records having the highest possible degree of accuracy and usefulness. Some attention will be given to the question of the reliability of the results obtained from a single raingage as applied to larger or smaller areas around it."

This thorough paper on the measurement of rainfall and snow opens with a discussion of the history of rain gages and of early observations, particularly those of the United States. Detailed descriptions of various forms of rain gages follow. Passing over many of these details, this review will cover particularly (1) errors of rainfall measurements, (2) suggested methods for the accurate measurement of snowfall, and (3) rainfall on mountain slopes as compared with raingage indications.

"ERRORS OF RAINFALL MEASUREMENTS.

"The usual errors to which rainfall records are subject include:

"1. Observational errors, personal equation, and mistakes.

"2. Instrumental or ratio error.

"3. Errors due to evaporation.
"4. Errors due to inclination of the gage funnel.
"5. Wind or exposure error.
"6. Location error.

"*Observational errors.*—The most usual observational error arises from recording the nearest hundredth inch less than the true amount, and from counting as traces all quantities less than 0.01 inch. If the observer will follow the rule of recording the nearest hundredth inch, whether greater or less than the true amount, and of counting as 0.01 inch any quantity greater than 0.005 inch and less than 0.015 inch, this error will be wholly obviated. As to mistakes—those of excess are apparently as likely to occur as those of deficiency."

There are many points about the reading and inspection of raingages that need attention. At most cooperative stations the raingages are read only once a day; and, unfortunately, some are read in the morning, and others in the afternoon. This makes local intercomparisons difficult. The frequently-found occurrence of certain irregularities in rainfall records, such as a lack of entries of traces, 0.01 or 0.02 inch, point to careless methods of observation, and indicate the need for much more frequent inspection of rainfall stations and talks with the observer. The need of keeping comparative records for a time when the location of the raingage is changed, and the value of no interruptions in rainfall records are readily appreciated without further discussion.

Instrumental error.—The selection of the proper type of raingage is the first consideration in providing an instrument which will record as closely as possible the actual amount of rainfall. "If it is assumed that a [cylindrical] gage can not catch more than [the] true amount, unless from outside causes * * *" a considerable amount of comparative data seem to indicate that 8 inches is the optimum diameter, notwithstanding the fact that some experiments have indicated that the catch of 8-inch gages is about 5 per cent less than the true rainfall. Among the recording types, the float or weighing gages give the most accurate results. Nevertheless, the total readings of gages of the tipping bucket type can be accurately checked by later measurements of the water retained in the gage.

A raingage itself may give erroneous measures of correct catches if the ratio between the size of the measuring tube and that of the funnel is not exactly that for which the measuring scale was graduated.

Evaporation loss.—Evaporation loss is usually negligible. The evaporation of water in the gage even in summer amounted in one test to only 0.01 inch in a week. The evaporation of the water that sticks to the funnel is in each instance equivalent to only about a third of 0.01 inch. In inaccessible regions where raingages must be left unvisited for considerable periods the use of a film of oil will prevent the evaporation of heavy falls of rain but facilitates the evaporation of water from light showers in which the water does not penetrate the oil.

Inclination errors.—With rain falling vertically gages at inclinations of 5°, 10°, and 15° will catch 0.4, 1.5, and 3.4 per cent less than they should. As rain does not usually fall vertically, however, "the effect of inclination of a raingage depends on the direction in which it is inclined relative to the direction of the rain-bearing wind. If the inclination of the gage is toward the wind and is less than twice the inclination of the rain, the gage will catch more than the true amount. * * * Since the rain does not always come from the same direction it is evident that an inclined gage may give results considerably in error in some showers and be quite nearly correct in other showers."

Wind or exposure error.—It has long been recognized that the decrease in the catch of gages with increased altitude above the surface is the result of wind action. In England raingages are exposed in grass-plots at least 6 feet in diameter and far enough from obstructions to give a fair catch. The top of the gage is 1 foot above the ground. In Germany raingages are at a height of 1 meter. In the United States, 4.5 feet has been found most satisfactory because of the greater susceptibility to (non-meteorological) disturbance at a lower elevation. Unless some sort of shield is provided to prevent upward air movements over the funnel, any gage, otherwise well-exposed as regards surrounding trees and buildings, may give unsatisfactory results. As shown by experiments in Russia, the deficiency may amount to perhaps 1 per cent in heavy rains, from 8 to 15 per cent in light rains, 18 to 20 per cent for wet snow, and 15 to 69 per cent for dry snow. At Providence, R. I., in the years 1909–1916, inclusive, five city gages showed mean rainfalls of from 39.42 to 41.51, while the gage on the roof of a tall building showed only 34.78 inches. This, however, is an extreme case. The catches of roof gages in other cities seem generally to be fairly close to those obtained at ground stations. The comparisons of 5 gages in Providence, 4 in Pawtucket, 6 at Fall River, and 8 in New Orleans show that the indications of any single gage under favorable conditions is generally within 5 per cent, and otherwise within 10 per cent, of the mean of all the other gages, in any single year. "[All in all,] the result of wind or exposure error is to make the recorded precipitation usually less than the true amount."

Location error.—A raingage may represent the amount of rain that falls in its immediate vicinity; but its indications are wanted to show the rainfall over an appreciable area, perhaps several square miles. "The result of error due to location of the raingage within the influence of a large wind eddy, is to make the recorded amount either greater or less than the true precipitation in the locality."[1]

Summary.—"Taken altogether, there is some preponderance of errors tending to make the measured less than the true amount of precipitation falling as rain, and the tendency is greatly increased for precipitation falling as snow."

SNOWFALL MEASUREMENT.

The measurement of snowfall is perhaps the weakest point in our precipitation records. It has long been recognized that most gages are useless for obtaining accurate snowfall measurements, even when fitted with a melting device. A new cylindrical snow sampler, diameter 8, length 30 inches, with a brass cutting rim, and a stopcock to let out the air when a cylinder of snow is being cut, has recently been devised by the author.

"Select a level space surrounded by shrubs or sparse trees. The open space or clearing should be 50 to 100 feet or more in diameter, depending on the height of the shrubs or trees. As a rule, snow will not drift nor be blown away near the middle of such a park or open space. In selecting the spot for snow measurement it is preferable to observe the conditions for a year in advance of its use. When snow falls at an angle, as it commonly does, a tree shadows the ground for some distance to the leeward and prevents the full depth of snow from reaching the ground. The spot chosen for making measurements must be suffi-

[1] Cf. MO. WEA. REV., 1915, 43: 318-321.—ED.

ciently remote from all trees to avoid an error from this source.

"Before the first snowfall, place on the ground a sheet of very thin board—plaster board or beaver board answers well. On the upper surface there should be secured by thumb tacks at the corners a sheet of white cloth with a rough surface—white flannel is good. The position of the board may be marked by two or three stiff wires stuck into the ground at a little distance from the board. When the first snowfall comes, a special snow can, described above, may be inverted over the cloth and pressed down firmly, rotating it slowly as it is pressed down. Then the remaining snow should be brushed off from the cloth, the board lifted, at the same time lifting and inverting the can with the board over its mouth. * * *.

"After a measurement the flannel cloth is, if necessary, dried, retacked on the snow board, and the snow board placed on the surface of the newly fallen snow where the snow is undisturbed, the board being pressed down just sufficiently so that the cloth surface is flush with the snow surface. The snow board should be inspected every day whether it snows or not, so as to keep its surface flush with the snow surface at all times.

"The use of the cloth is twofold: (1) It provides a surface with friction conditions much more closely resembling those of snow than could be obtained by the use of the board alone. (2) It provides a surface as nearly as can readily be obtained, equivalent to a snow surface in its capacity to absorb and radiate heat, and so prevents loss by melting when snow falls in relatively warm air."

Snow samplers of another type for measuring mountain accumulations of snow in spring are very useful for estimating a summer water supply.[2]

RAINFALL ON MOUNTAIN SLOPES AS COMPARED WITH THEORETICALLY PERFECT RAINGAGE INDICATIONS.

"There is a matter in connection with the inclination at which rain falls, which is sometimes of great importance, but which seems to have been generally overlooked. If a rain-bearing wind blows against a mountain slope, then the amount of rain falling on the mountain slope will generally be greater than the amount which would fall on an equal horizontal projected area and greater than the amount caught or measured by a horizontal rain gage.

"In a similar manner the actual precipitation on the leeward side of the slope may be materially less than indicated by a horizontal rain gage. The southeast slope of the Catskill Mountains in New York State affords an excellent illustration of a case where the actual rainfall is apparently greater than the measured amount. The average slope of the mountain side is about 30°. If the rain is blown against this slope at an angle of 15° to the vertical, then the actual precipitation on the projected area would be 1.16 times the amount measured by a horizontal raingage.

"If the run-off of a stream for the winter period, November to April, inclusive, is compared with the measured precipitation for the same period, it will sometimes be found that the measured run-off is the greater. However, the ground water and surface storage is usually larger at the end than at the beginning of the winter period, so that the measured run-off will usually represent less than the total available water supply."—*C. F. B.*

DISCUSSION.

Ever since, and in all probability before, the famous comparisons at Rothamsted, it has been evident, assuming that accurate serviceable instruments are used (and at present there is no valid excuse for considering any other kind), that the only important errors in records of precipitation are due to bad exposure and faulty methods of observation. The six different kinds of errors referred to by Mr. Horton are found in these two classes.

Some differences between gages under comparison can not be explained, but apparently if there are important differences between gages of different sizes they would have appeared somewhere in comparisons that have included the 0.001-acre gage, whose area is nearly 4 square meters, and the smaller ones having an area a thousand times smaller.

Comparisons of several patterns of gages at Blue Hill Observatory during a long period of time indicate that:

(1) Gages fitted with a Nipher screen made of wire cloth and having a diameter of at least twice that of the funnel are more efficient than unshielded gages during high winds.

(2) Apparently the best possible conditions are obtained when gages shielded in this way are placed with their funnels about 0.3 meter above the ground and inside an inclosure whose walls are composed of coarse wire cloth and placed at a distance from the gages equal to about twice their height.

Personal experience with various methods of measuring snow indicates that:

(1) Cylindrical "catch" gages, of which the length of the funnel is greater than one-third its diameter, should under no circumstances be used for measuring snow.

(2) The only moderately satisfactory "catch" gage has a very short funnel terminating in a receiver at least twice as large as the funnel and fitted with a Nipher screen as already described.

(3) It is best that "catch" gages for snow, particularly where an appreciable interval of time occurs between the end of the storm and measurement, should be made self-recording, for then it is possible to allow for evaporation and drifting due to increase or change of wind. Records from such instruments supplemented by surveys with samplers should yield more accurate information concerning the amount, rate, and duration of snowfall than is available with means in use at present. For use in sparsely settled regions it is easily possible now to produce gages of this kind capable of running several months with one winding of the clock.—*S. P. Fergusson.*

[2] A discussion of these is planned for a later issue of the REVIEW.—ED.

THE RELATION OF RAINFALL TO CONFIGURATION.

By CARLE SALTER, Joint Director of the British Rainfall Organization.

[The Institution of Water Engineers, London, 1919.]

The author has treated the subject on the basis of the average annual rainfall at selected stations of the British Rainfall Organization, having an average computed from 35 to 40 years continuous observations. In cases where no averages of that duration were available a shorter term was used after correction by comparison with one or more adjacent long-term records.

The closeness of the network of rainfall stations in Great Britain permits the study of the precipitation-altitude relation in much greater detail than elsewhere for an equal area, although this important advantage is offset somewhat by lack of topographic contrast except in the west of Scotland and in Wales.

The great majority of the averages used were for altitudes below 1,000 feet.

For the purpose of discussion the author classifies rainfall according to the different circumstances under which air is forced to ascend. In this respect he follows Curtis.[1] In brief these different circumstances may be grouped under three heads, viz.: (1) Convectional, (2) cyclonic, and (3) orographic.

It would seem to the writer that there is more or less overlapping in groups 2 and 3, and that for regions where the dominant weather control is cyclonic, as on the west coast of Europe and North America, the rainfall should be classed as cyclonic rather than orographic.

The configuration of the land it is pointed out by the author only slightly affects the distribution of convectional rains, these being very largely local and more apt to occur in low-lying districts than in mountain regions. While the region of convective rains in the United States is largely without surface relief of importance, yet there is a district in the southwest—New Mexico and Arizona—largely mountainous where convective rains prevail during July and August. These rains are mostly confined to the higher altitudes; I would, therefore, hesitate to say that configuration affects but slightly the distribution of convective rains. It may be that by reason of the extreme dryness of the air in that region the rain is evaporated before reaching the lowlands.

[1] U. S. Department of Agriculture, Forestry Division, Bulletin No. 7, 1893, Forest Influences, pp. 187, 188.

With regard to the second class—cyclonic rains—the author concludes that there is probably some general updraft of air near the center of cyclonic systems, but that the rainfall directly associated with such updraft is usually slight. The more general and heavier rain in association with cyclonic systems is probably due to the interaction of two great air currents at different temperatures which cross one another's path and, further, "they are very much more widespread than convectional thunderstorm rains and, if true to type, are absolutely independent of land configuration." Why the rains produced by the interaction of the two great currents should be independent of land configuration is not clear to the reviewer.

Since the bulk of the elevated land in Great Britain is near the west coast, the best examples of orographic rains are found in that region. The influence of a background of elevated land upon the rainfall at sea level to the windward is noticeable on the west and south coast as compared with the east coast.

Examples are given to illustrate the fact, for it seems to be duly authenticated not only in Great Britain but also in other lands that the relatively high rainfall of valley bottoms having steep sides may be attributed to the altitude of the sides rather than the bottoms, and this is particularly true in the case of valleys transverse to the direction of the rain winds.

The average rate of increase of rainfall in windward slopes per 100 feet increase in altitude varies within wide limits. In the simple case of rising land facing the sea the increase may be from 1.5 to 2 inches per 100 feet increase in altitude, but this rate may be reduced to a smaller figure when the slope of the land is reduced. The author finds in the case of fairly steep ridges that the maximum rainfall occurs slightly on the leeward side of the crest regardless of the altitude of the spot on which it falls.

On leeward slopes of high land rainfall diminishes steadily. For the Pennines it was found, broadly speaking, that annual rainfall decreases 1 inch per 100 feet above 1,000 feet, increasing to 2 inches per 100 feet below 500 feet of altitude; other slopes gave greater irregularity in the decrease per 100 feet, probably due to the effect of local conditions.—*A. J. H.*

STORM RAINFALL OF EASTERN UNITED STATES.

By the Engineering Staff of the Miami Conservancy District Techincal Reports, Part V.

[Dayton, Ohio, 1917, pp. 309 with 114 figs.]

This report consists of a critical analysis of the voluminous mass of excessive rainfall data contained in the manuscript records of the United States in the archives of the United States Weather Bureau in Washington, D. C. For the purpose of studying seasonal and geographical distribution, frequency and cyclic variation of great rain storms the 25 year period 1892–1916 was selected, and 160 great storms were found in this period. The limiting condition for any one of these storms was that it must include records from at least five stations each having a three-day precipitation equaling or exceeding 6 inches. These storms were divided into two groups, northern and southern storms, and a chronological list is given in Tables 4 and 5. The procedure adopted consisted of the following steps: (1) assembling the rainfall data; (2) selecting the greatest one-day, two-day rainfall, and so on; (3) plotting the rainfalls on a large-scale map; (4) drawing the isohyetals; (5) measuring the areas within the isohyetals; (6) computing the average depth within the isohyetals; (7) drawing on coordinate paper the time-area-depth curves using as coordinates the area in square miles and the average depth of rainfall over the corresponding area. Much stress was laid upon the determination of the time-area-depth relations in these storms and also on the question how great a rainfall may be expected in the northeastern United States? An interesting conclusion from a purely climatological standpoint drawn from this study was that the variations in total annual rainfall in Eastern United States depend chiefly upon the occurrence of great storms. While the report was prepared from the engineering standpoint it contains, nevertheless, many results of great interest to climatologists and other students of rainfall statistics.—*A. J. H.*

PANAMA RAINFALL.

By H. G. CORNTHWAITE, Chief Hydrographer.

[Dated: Balboa Heights, C. Z., Jan. 31, 1919.]

SYNOPSIS.—The writer sketches the geographical distribution of the rainfall in Panama, and follows with an account, with tables and figures, of monthly and hourly precipitation, local showers, and excessive rainfall. Whatever rain occurs on the Isthmus must be attributed to local convection currents in conjunction with the deflective effects of hills and mountains on such winds as there are.

The rainfall on the north side exceeds that on the south side of the Isthmus, and is greatest on the north coast and locally on the higher portions of the Caribbean slope. The mean annual rainfall at Colon is 129.04 inches; at Porto Bello 169.15 inches, and at Balboa, 91.61 inches.

An excessive downpour in a brief period, probably 2.48 inches in 5 minutes at Porto Bello, May 1, 1910, seems to have been the most intense rainfall ever recorded.—H. L.

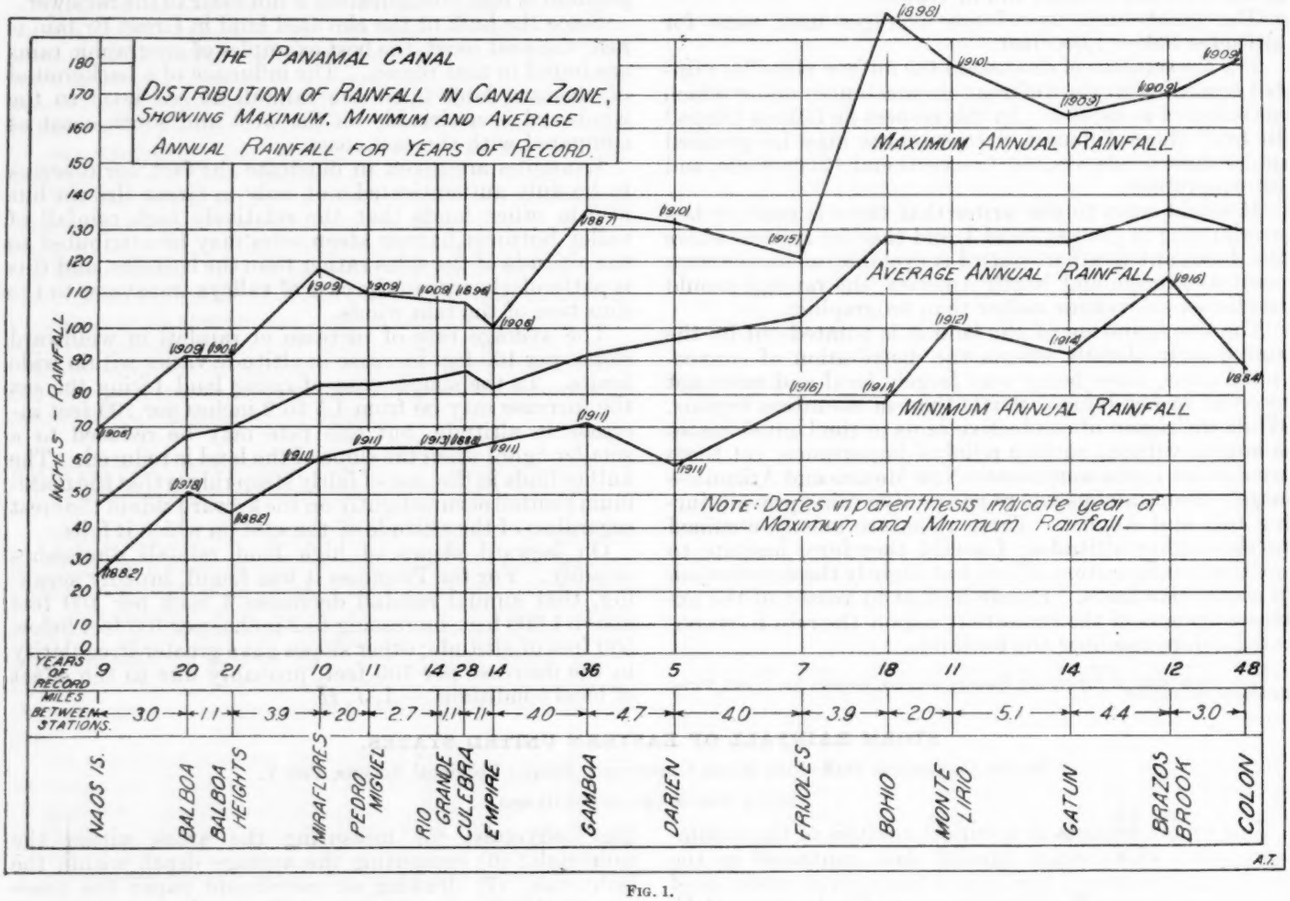
THE PANAMAL CANAL
DISTRIBUTION OF RAINFALL IN CANAL ZONE, SHOWING MAXIMUM, MINIMUM AND AVERAGE ANNUAL RAINFALL FOR YEARS OF RECORD.
MAXIMUM ANNUAL RAINFALL
AVERAGE ANNUAL RAINFALL
MINIMUM ANNUAL RAINFALL
NOTE: Dates in parenthesis indicate year of Maximum and Minimum Rainfall
INCHES - RAINFALL
YEARS OF RECORD 9 20 21 10 11 14 28 14 36 5 7 18 11 14 12 48
MILES BETWEEN STATIONS. 3.0 1.1 3.9 2.0 2.7 1.1 1.1 4.0 4.7 4.0 3.9 2.0 5.1 4.4 3.0
NAOS IS. BALBOA BALBOA HEIGHTS MIRAFLORES PEDRO MIGUEL RIO GRANDE CULEBRA EMPIRE GAMBOA DARIEN FRIJOLES BOHIO MONTE LIRIO GATUN BRAZOS BROOK COLON
A.T.

FIG. 1.

[1]"The cause of rainfall is to be found in the operation of certain general principles of physics, influenced more or less by local conditions. Rainfall is due to the condensation and precipitation of water vapor in the atmosphere, which has been derived primarily from the ocean by the process of evaporation. Whenever from any cause the moisture-laden air is sufficiently cooled, condensation and consequent precipitation take place. Three processes are primarily concerned in the production of rain, acting either singly or in combination. These factors are:

"(1) Convective currents [local].

"(2) Hills and mountains, which cause deflection of atmospheric currents.

"(3) Cyclonic circulation."

Since the Isthmus of Panama is in that section of the globe where the influence of convection is very great and where cyclonic disturbances are almost unknown, it follows that the greater part of the Isthmian rainfall must be attributed to the first two processes mentioned above.

Panama is situated in the Torrid Zone, where tropical weather conditions prevail. The year is divided into two seasons, a dry season of approximately four months duration, January to April, inclusive, and a rainy season extending over the remaining eight months of the year.

GEOGRAPHICAL DISTRIBUTION OF RAINFALL.

Rainfall in the Canal Zone and vicinity is heaviest along the Atlantic coast and in sections of the upper Chagres River drainage basin, diminishing gradually as the Pacific coast is approached. Practically all of the moisture-laden winds blow from off the Atlantic and the greater percentage of the surplus moisture carried by these winds is precipitated on the Atlantic side of the continental divide.

A large percentage of the rainfall in the Canal Zone is of the afternoon thundershower type, caused by con-

[1] Quoting in part from article by C. M. Saville on the hydrology of the Panama Canal.

vective air circulation resulting from the excessive heating of the land surface during the daytime. This rain producing agency is less active out in Panama Bay, which accounts for the abrupt decrease in rainfall on Naos Island and Taboga, compared with the rainfall on the mainland.

The lightest annual rainfall of record on the Isthmus was 25.14 inches on Naos Island in 1882. The total rainfall at Taboga during the year 1918 was but 30.09 inches, and a long period record at Taboga probably would show still lighter rainfall.

The heaviest average annual rainfall of any station on the Isthmus is approximately 170 inches at Porto Bello, favorably located on the Atlantic coast near the headwaters of the Boqueron arm of the Chagres River. The total rainfall at Porto Bello in the year 1909 amounted to 237.28 inches. This is the heaviest annual rainfall of record at any station on the Isthmus, and it is exceeded in only a few known regions of the earth.

Figure 1 shows the distribution of annual rainfall across the Isthmus, as well as the maximum range in yearly rainfall at the various stations.

The annual rainfall in Panama is much less variable and more *dependable* than the rainfall in many sections of the Temperate Zone. This characteristic of Isthmian rainfall is valuable in connection with the operation of the Panama Canal, as it insures a dependable water supply. Figure 2 shows the variability of annual rainfall in the Canal Zone compared with the rainfall at selected stations in the United States. The curves show maximum and minimum annual rainfall in percentages of the annual means.

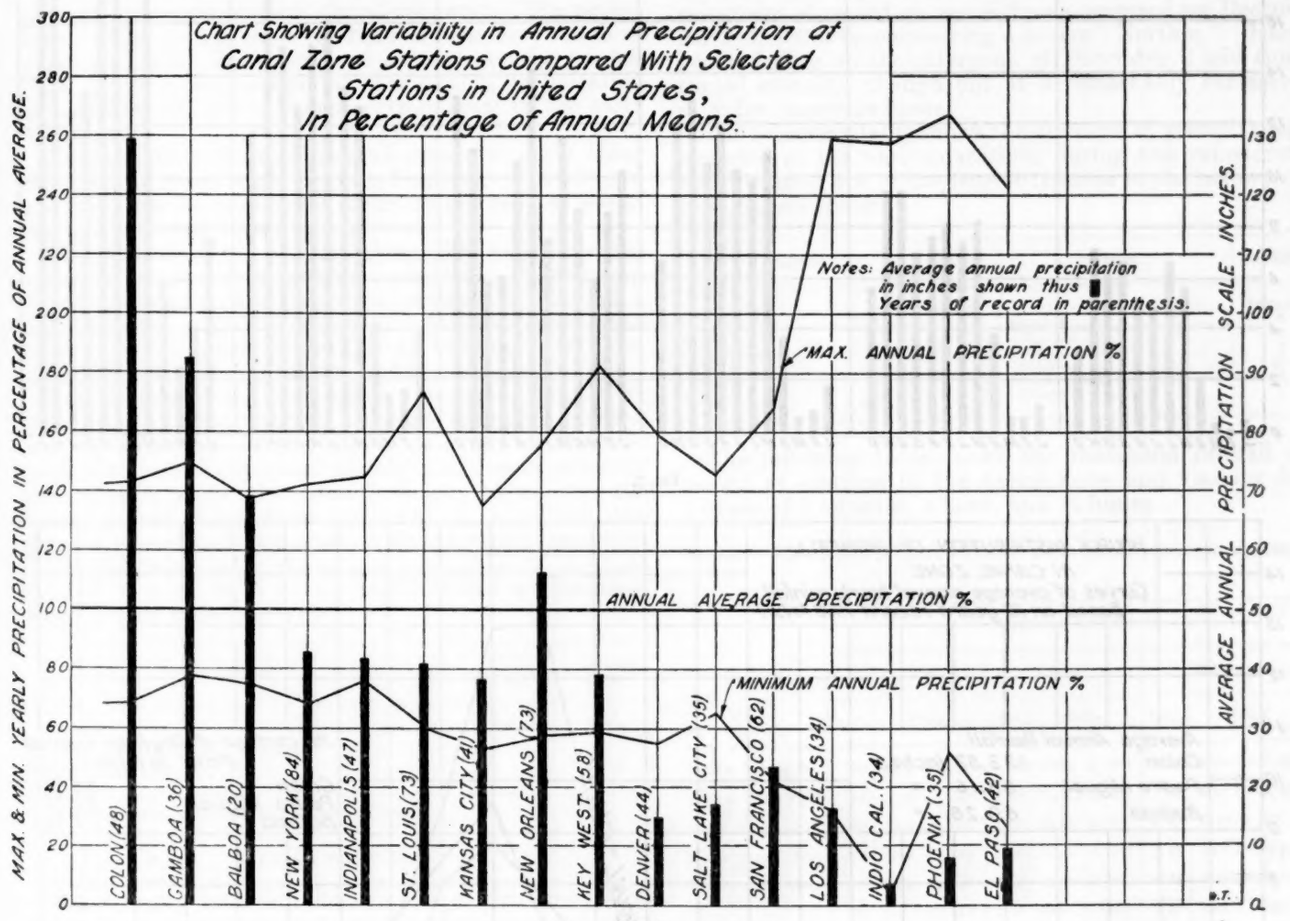
Chart Showing Variability in Annual Precipitation at Canal Zone Stations Compared With Selected Stations in United States, In Percentage of Annual Means.
MAX & MIN YEARLY PRECIPITATION IN PERCENTAGE OF ANNUAL AVERAGE.
AVERAGE ANNUAL PRECIPITATION SCALE INCHES.
Notes: Average annual precipitation in inches shown thus
Years of record in parenthesis.
MAX. ANNUAL PRECIPITATION %
ANNUAL AVERAGE PRECIPITATION %
MINIMUM ANNUAL PRECIPITATION %
COLON (48)
GAMBOA (36)
BALBOA (20)
NEW YORK (84)
INDIANAPOLIS (47)
ST. LOUIS (73)
KANSAS CITY (41)
NEW ORLEANS (73)
KEY WEST (58)
DENVER (44)
SALT LAKE CITY (35)
SAN FRANCISCO (62)
LOS ANGELES (34)
INDIO CAL. (34)
PHOENIX (35)
EL PASO (42)
G.T.

FIG. 2.

MONTHLY DISTRIBUTION.

The monthly distribution of rainfall at selected stations in the Canal Zone and vicinity is shown on figure 3. The season of the year from January to April, inclusive, is general recognized as the dry season on the Isthmus. Rainfall in the dry season usually consists of light local showers, but heavy rains of a more general character occur at times along the Atlantic coast accompanying storms of the "norther" type that occassionally reach as far south as the Atlantic coast of the Isthmus during the dry season.

The rainy season extends over the remaining eight months of the year. The lines of demarkation between dry-season and rainy-season conditions are not constant nor always clearly marked. In some years the dry season begins as early as December 1, while in other years rainy season conditions continue until the end of January or later.

March is usually the month of least rainfall and May and November are the months of heaviest rainfall.

An inspection of figure 3 shows that the rainfall at Bocas del Toro is somewhat lighter than the Colon rain-

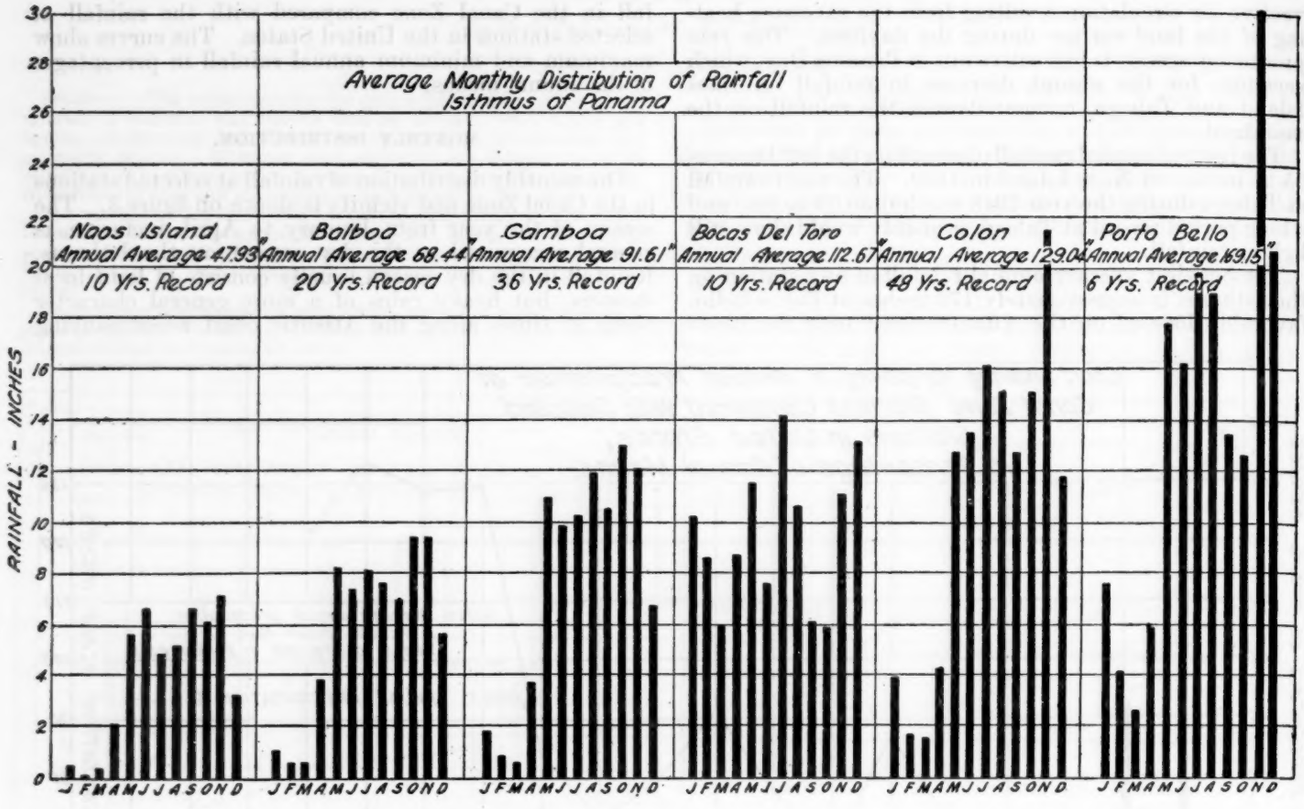
Average Monthly Distribution of Rainfall
Isthmus of Panama
RAINFALL - INCHES
Naos Island
Annual Average 47.93"
10 Yrs. Record
Balboa
Annual Average 68.44"
20 Yrs. Record
Gamboa
Annual Average 91.61"
36 Yrs. Record
Bocas Del Toro
Annual Average 112.67"
10 Yrs. Record
Colon
Annual Average 129.04"
48 Yrs. Record
Porto Bello
Annual Average 169.15"
6 Yrs. Record
J F M A M J J A S O N D

FIG. 3.

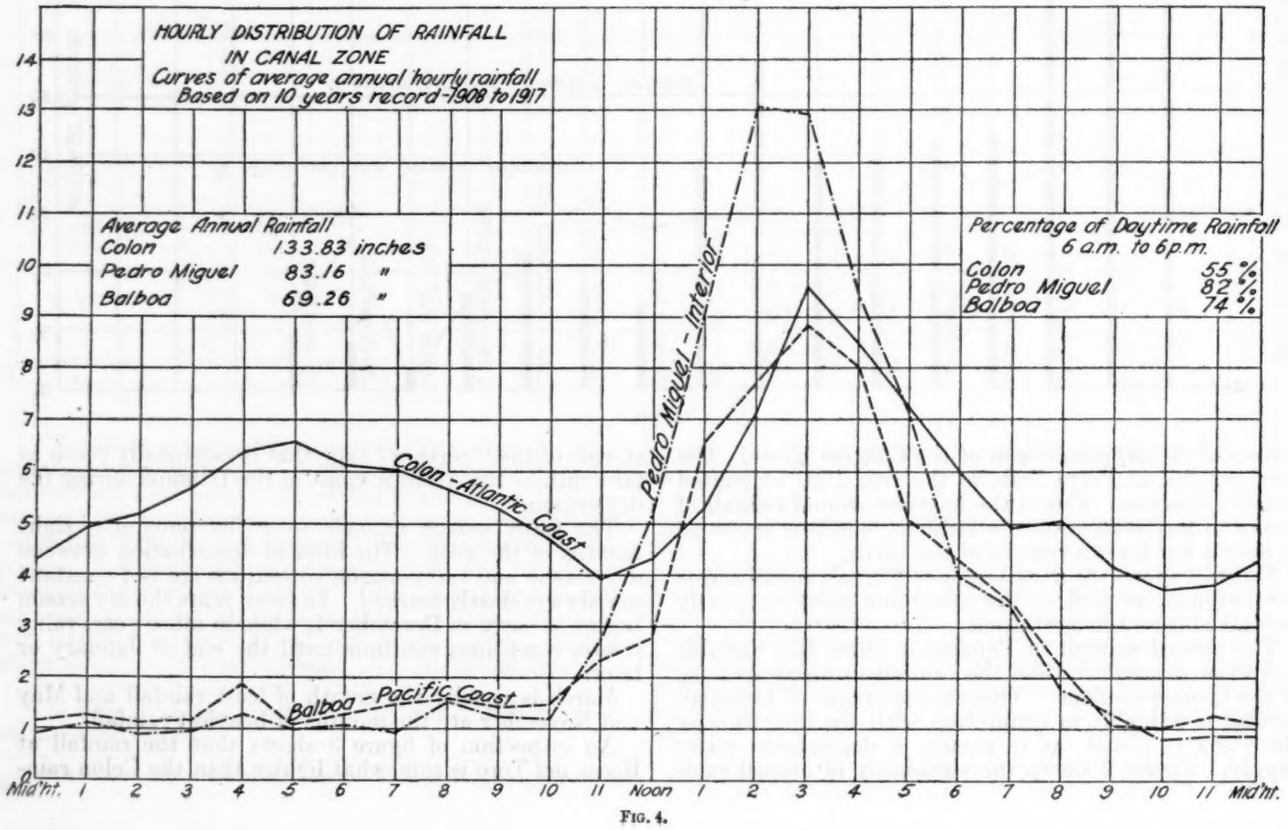
HOURLY DISTRIBUTION OF RAINFALL
IN CANAL ZONE
Curves of average annual hourly rainfall
Based on 10 years record-1908 to 1917
Average Annual Rainfall
Colon 133.83 inches
Pedro Miguel 83.16 "
Balboa 69.26 "
Percentage of Daytime Rainfall
6 a.m. to 6 p.m.
Colon 55 %
Pedro Miguel 82 %
Balboa 74 %
Colon - Atlantic Coast
Pedro Miguel - Interior
Balboa - Pacific Coast
Mid'nt. 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3 4 5 6 7 8 9 10 11 Mid'nt.

FIG. 4.

fall, but it is remarkable principally on account of its radically different monthly and seasonal distribution. There are two periods of heavy rainfall at Bocas, one about July and another in December and January. There are also two periods of light rainfall, one in March and another in September–October. There is no clearly marked dry season at Bocas, as considerable rain falls during the driest months. The reason for this radically different rainfall distribution at Bocas del Toro is not clear, but it probably is due to the character and direction of prevailing winds and the position of adjacent mountain ranges.

HOURLY DISTRIBUTION.

A large percentage of Panama rainfall comes in the form of afternoon tropical thundershowers. The period from 2 p. m. to 3 p. m. is the hour of heaviest rainfall as a general rule. The curves of average hourly rainfall show (fig. 4) a principal period of minimum precipitation around 10 p. m., and a secondary minimum in the early morning.

Nearly half of the total rainfall occurs at night along the Atlantic coast, while near the Continental Divide and along the Pacific coast only about 25 per cent or less of the total rainfall occurs at night.

The heavier night rainfall along the Atlantic coast seems to be due to a smaller percentage of afternoon thundershowers and a larger percentage of rains of a more general character along the Atlantic coast than occur over the other sections of the Isthmus. Many of these general rains occur at night.

The chilling of the land surface during the night by the escape of heat through outward radiation and the upward deflection of the winds in passing over the land mass also tend to increase the night and early morning precipitation along the Atlantic coast, by cooling the warm, humid winds from the Atlantic, until the dew point is passed and condensation and precipitation occur.

The following table shows the percentage of daytime rainfall (6 a. m. to 6 p. m.) at three selected stations, based on 10 years' records:

Stations.	Daytime precipitation.	Annual total.
	Per cent.	*Inches.*
Balboa (Pacific coast)	74	69.25
Pedro Miguel (near Continental Divide)	82	83.16
Colon (Atlantic coast)	55	133.83

Curves of average hourly rainfall are shown on figure 3.

LOCAL SHOWERS.

Many heavy Isthmian showers are of extremely local character and very limited extent. An examination of the records shows some remarkable differences in the quantity of rain falling within narrow territorial limits. The following table gives a comparison of the rainfall at adjacent stations for selected showers of limited extent:

Station.	Rainfall.	Station.	Rainfall.	Distance between stations.	Date of shower.
	Inches.		*Inches.*	*Miles.*	
Monte Lirio	6.76	Brazos Brook	0.97	6	Feb. 8, 1910
Gamboa	3.21	Empire	.52	4	July 3, 1910
Gatun Evapor. Sta.	4.05	Gatun	.89	1	May 23, 1911
Gorgona	5.45	San Pablo	1.27	3.5	May 13, 1911
Miraflores	4.04	Pedro Miguel	.35	2	Dec. 30, 1912
Empire	3.36	Culebra	.59	1	June 7, 1913
Brazos Brook	3.75	Colon	.31	3	Dec. 1, 1913
Rio Grande	3.24	Pedro Miguel	.33	2.7	June 1, 1917
Empire	4.89	Gamboa	.66	4	Oct. 21, 1918

EXCESSIVE PRECIPITATION.

The greater part of the rainfall on the Isthmus comes in the form of heavy tropical downpours of short duration and relatively limited extent.

Late in the rainy season, usually in November and December, rainstorms of a more general character and of longer duration may occur. These general rainstorms frequently accompany storms of the "Norther" type and they continue at times for 24 hours or longer. Some of them extend over the entire Canal Zone and adjacent territory, while others are confined to the Atlantic coast of the Isthmus. The dry-season storms of this character are more likely to be confined to the Atlantic coast and adjacent territory. What is perhaps the heaviest general rainstorm of record on the Isthmus occurred on December 2–3, 1906, accompanying a severe "Norther." Rain began falling on the afternoon of December 2 and continued steadily, though not at a remarkably excessive rate, for nearly 24 hours.

The following table shows the amounts of precipitation recorded at the various stations during this rainstorm, which caused one of the largest freshets in the history of the Chagres River:

Station.	Rainfall.	Station.	Rainfall.
	Inches.		*Inches.*
Balboa	2.41	Gamboa	6.29
Ancon	3.18	Alhajuela	8.19
Rio Grande	5.58	Bohio	6.13
Culebra	5.55	Gatun	10.48
Camacho	5.53	Brazos Brook	8.96
Empire	6.15	Cristobal	8.47

The following table shows the maximum rainfall of record at stations in the Canal Zone and vicinity for periods of 5 minutes, 1 hour, and 24 hours:

TABLE 1.—*Maximum rainfall in Canal Zone October, 1905, to January, 1919.*

Stations.	Maximum rainfall.					
	5 minutes.		1 hour.		24 hours.[1]	
	Inch.	Date.	Inch.	Date.	Inch.	Date.
Balboa (June 10, 1906).	.90	May 12, 1912	5.86	June 2, 1906	7.57	Nov. 16–17, 1906.
Balboa Heights (Oct. 1, 1905).	.64	Aug. 7, 1908	3.98	Oct. 9, 1911	7.23	May 12–13, 1912.
Miraflores (June 19, 1914).	.50	Sept. 6, 1917	4.09	Sept. 6, 1917	4.75	Sept. 6, 1917.
Pedro Miguel (Jan. 1, 1908).	.60	Nov. 11, 1908	3.46	Sept. 6, 1917	5.45	Nov. 19–20, 1917.
Rio Grande (Dec. 29, 1905).	.75	July 24, 1908	4.14	Nov. 20, 1917	8.24	Nov. 19–20, 1917.
Empire (July 18, 1906).	.60	July 25, 1906	4.19	Oct. 21, 1908	6.15	Dec. 3, 1906.[2]
Gamboa (Nov. 18, 1905).	.59	July 27, 1908	3.32	May 11, 1911	6.56	Dec. 2–3, 1906.
Alhajuela (Mar. 31, 1907).	.60	July 20, 1909	4.19	July 8, 1915	8.19	Dec. 2–3, 1906.[2]
Gatun (Oct. 1, 1905)	.62	{Aug. 3, 1912 {Aug. 12, 1914	4.72	Aug. 12, 1914	10.48	Dec. 3, 1906.[2]
Bohio (Oct. 1, 1905)	.67	June 16, 1909	4.51	Aug. 7, 1908	8.85	Aug. 7–8, 1908.
Colon (Oct. 1, 1905).	.64	Aug. 25, 1909	4.90	Oct. 8, 1909	8.53	Dec. 2–3, 1906.
Porto Bello (May 1, 1908).[3]	[4] 2.48	Nov. 29, 1911	4.53	Nov. 29, 1911	10.86	Dec. 28–29, 1909.

[1] Maximum rainfall in 24 consecutive hours.
[2] No automatic record on this date, total for 24 hours ending at noon.
[3] Station closed in August, 1914, and reopened in December, 1918.
[4] Approximate, automatic record indistinct due to unusually excessive rate of rainfall. [This rate exceeds that of 205 mm. (8.07 in.) in 20 minutes at Curtea-de-Arges, Roumania, July 7, 1889, heretofore considered the greatest on record.—ED.]
Dates in parenthesis refer to the installation of automatic raingages.

A comparison of the heaviest 24-hour rainfall recorded on the Isthmus with the heaviest known rainfalls in

other regions of excessive precipitation is presented in the following table. It will be noted that the maximum 24-hour rainfall of record on the Isthmus; approximately 11 inches, has been exceeded at several localities in the United States, where the average annual precipitation is much less than the annual average in Panama.

TABLE 2.—*Excessive rainfalls in periods of about a day.* [1]

Station.	Date.	Rainfall.		Duration.
		Inches.	Millimeters.	
Porto Bello, R. P.	Dec. 28–29, 1909	10.9	276	24 hours.
Robertsdale, Ala.	Sept. 28, 1917	17.5	444	1 day.
Catskill, N. Y.	July 26, 1819	18.0	457	7½ hours.
St. George, Ga.	Aug. 28–29, 1911	18.0	457	17 hours.
Montell, Tex.	June 28–29, 1913	20.6	523	18½ hours.
Fort Clark, Tex.	June 14–15, 1880	21.3	541	22 hours.
Alexandria, La.	June 15–16, 1886	21.4	544	24 hours.
Altapass, N. C.	July 15–16, 1916	22.22	564	Do.
Adjuntas, Porto Rico.	Aug. 18, 1899	23.0	584	Do.
Hills above Bombay, India.	Ency. Britannica.	24.0	610	1 night.
Genoa, Italy.	do.	30.0	762	26 hours.
Gibraltar.	do.	33.0	838	Do.
Silver Hill, Jamaica.	Nov. 6, 1909	30.5	775	1 day.
Nedunkem, Ceylon.	Dec. 15–16, 1897	31.8	807	24 hours.
Honomu, Hawaii.	Feb. 20, 1918	31.95	812	1 day.
Laupchoehoe, Hawaii.	Dec. 24, 1901	41.3	1,049	28 hours.
Queensland.		40.0	1,016	24 hours.
Cherrapunji, India.	June 14, 1876	40.8	1,036	Do.
Baguio, Philippine Islands.	June 14–15, 1911	45.99	1,168	Do.

[1] Table amplified by Editor, mostly from MONTHLY WEATHER REVIEW, and Engineering News Record, vol. 76, p. 1001, 1916.

It is possible that quantities of rain greater than any listed above have fallen over very limited areas in the southern and southwestern sections of the United States.

The record of 45.99 inches of rainfall in 24 hours at Baguio, P. I., on July 14–15, 1911, during the passage of a severe typhoon is, so far as known, a world's rainfall record for a period of 24 consecutive hours.

Table No. 4 gives a comparison of the annual precipitation at Canal Zone stations and selected stations in the United States, while table No. 5 presents the monthly precipitation for maximum, minimum and average years at the principal stations in the Canal Zone and vicinity.

TABLE 3.—*Excessive rainfalls in periods of 5 minutes to 4 hours.* [1]

Station.	Date.	Rainfall.		Duration.
		Inches.	Millimeters.	
Porto Bello, R. P.	May 1, 1908	[2] 2.48	63	5 minutes.
Balboa, C. Z.	June 10, 1906	0.9	23	Do.
Fort McPherson, Nebr.	May 27, 1868	1.5	38	Do.
Paterson, N. J.	July 13, 1880	1.5	38	8 minutes.
Galveston, Tex.	June 4, 1871	3.9	100	14 minutes.
Curtea-de-Arges, Roumania.	July 7, 1889	8.1	205	20 minutes.
Guinea, Va.[3]	Aug. 24, 1906	[2] >9.25	>235	About 30 minutes.
		[2] >11.5	>292	Est. 30–45 minutes.
Newtown, Pa.	Aug. 5, 1843	5.5	140	40 minutes.
Tridelphia, W. Va.	July 19, 1888	6.9	175	55 minutes.
Palmetto, Nev.	Aug. 7, 1890	8.8	224	1 hour.
Campo, Calif.	Aug. 12, 1891	[2] 11.5	292	80 minutes.
Newtown, Pa.	do.	13	330	3 hours.
Concord, Pa.	do.	[2] 16	406	Do.
Basseterre, St. Kitts.	Jan. 12, 1880	[2] 23±	abt. 584	4 hours.

[1] Table amplified by Editor, largely from Greely's "American Weather," New York, 1888; and MONTHLY WEATHER REVIEW. See also table by C. P. Birkinbine, p. 59, in A. P. Towell's, "Sewerage," New York, 1918.
[2] Probably world's records.
[3] Pails ran over. See MONTHLY WEATHER REVIEW, 1906, 34, pp. 406–407.

TABLE 4.—*Annual precipitation.*

Station.	Maximum year.		Minimum year.		Annual mean (inches).	Years of record.
	Inches.	Year.	Inches.	Year.		
Colon	183.41	1909	86.54	1884	129.04	48
Gamboa	136.19	1887	70.67	1911	91.61	36
Balboa	93.06	1909	50.90	1918	68.44	20
New York	59.68	1859	28.78	1835	42.47	84
Indianapolis	57.65	1876	30.33	1901	40.99	45
St. Louis	68.83	1858	23.28	1871	40.10	73
Kansas City	50.25	1898	19.04	1886	37.69	41
Denver	22.96	1909	7.75	1911	14.52	44
Salt Lake City	23.64	1875	10.33	1890	16.33	35
San Francisco	38.82	1884	9.31	1898	23.25	62
Los Angeles	40.29	1884	4.83	1898	15.58	34
Indio, Calif.	7.10	1906	Trace.	1894	2.76	34
Phoenix	19.73	1905	3.77	1885	7.39	35
El Paso	21.81	1856	2.22	1891	9.06	42
New Orleans	85.73	1875	31.07	1899	55.63	63
Key West	69.69	1870	22.00	1893	38.40	58

TABLE 5.—*Monthly rainfall for maximum and minimum years, and averages.*

[Inches.]

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Porto Bello:													
Maximum year 1909	20.90	6.82	3.56	12.56	9.69	17.70	26.33	13.83	13.99	8.70	45.03	58.17	237.28
Minimum year 1912	.67	1.64	.60	.54	16.65	19.77	24.21	14.15	15.03	17.01	25.82	11.52	147.61
6-year average	7.51	4.13	2.49	5.86	17.74	16.12	19.77	18.93	13.28	12.53	30.16	20.63	169.15
Bocas del Toro:													
Maximum year 1910	33.66	6.98	3.61	17.30	13.97	10.12	17.20	7.61	5.27	3.16	6.54	21.45	146.87
Minimum year 1915	2.37	9.90	8.21	10.09	7.07	4.55	7.59	8.20	2.55	4.64	6.35	5.92	77.44
10-year average	10.18	8.64	5.83	8.67	11.40	7.47	14.09	10.48	6.06	5.81	11.06	12.98	112.67
Colon:													
Maximum year 1909	10.61	1.92	1.85	3.56	7.21	17.49	12.83	15.42	16.33	19.31	42.50	34.38	183.41
Minimum year 1884	3.39	.39	.39	4.33	10.16	10.32	15.59	13.27	9.37	8.66	7.05	3.62	86.54
48-year average	3.85	1.67	1.61	4.21	12.71	13.38	16.02	15.00	12.67	14.89	21.34	11.69	129.04
Alhajuela:													
Maximum year 1909	2.72	3.71	.29	3.54	14.32	19.73	13.64	8.15	7.50	19.32	36.22	22.90	152.04
Minimum year 1913	.96	.22	.08	.72	12.63	11.51	6.99	10.92	8.82	6.41	16.56	1.59	77.41
19-year average	1.03	.78	.49	3.68	12.25	12.51	12.44	12.51	11.69	14.01	14.35	5.94	101.68
Gamboa:													
Maximum year 1887	2.20	.08	.28	6.85	11.03	19.45	14.02	19.17	11.50	14.88	24.06	12.68	136.20
Minimum year 1911	.11	.71	.38	4.01	14.53	6.98	7.26	7.68	5.20	12.75	10.09	.97	70.67
36-year average	1.77	.86	.74	3.60	10.83	9.78	10.21	11.90	10.41	12.79	12.01	6.62	91.61
Culebra:													
Maximum year 1896	2.34	.39	3.06	16.70	7.40	7.08	8.18	17.70	8.35	8.10	24.10	3.64	107.04
Minimum year 1888	.24	.02	.53	.33	11.41	7.99	2.92	6.55	11.28	5.75	9.55	7.71	64.28
28-year average	1.60	.67	.58	3.69	11.14	8.84	9.43	10.05	10.74	11.43	12.42	6.90	87.49
Balboa:													
Maximum year 1909	1.45	1.69	.14	2.83	9.69	12.06	14.92	6.86	4.11	11.20	15.99	12.12	93.06
Minimum year 1918	1.02	.00	1.32	4.33	6.45	4.57	4.32	3.75	6.58	8.52	8.62	1.42	50.90
20-year average	1.07	.63	.67	3.80	8.18	7.30	8.06	7.62	6.97	9.32	9.31	5.51	68.44
Naos Island:													
Maximum year 1906	.31	.29	.02	6.56	7.21	11.34	8.79	5.89	3.29	3.76	16.76	4.74	68.96
Minimum year 1882	.00	.02	.02	.94	4.58	5.09	1.64	1.14	1.12	2.72	5.03	2.84	25.14
10-year average	.43	.11	.31	2.05	5.43	6.59	4.76	5.10	6.70	6.12	7.17	3.16	47.93

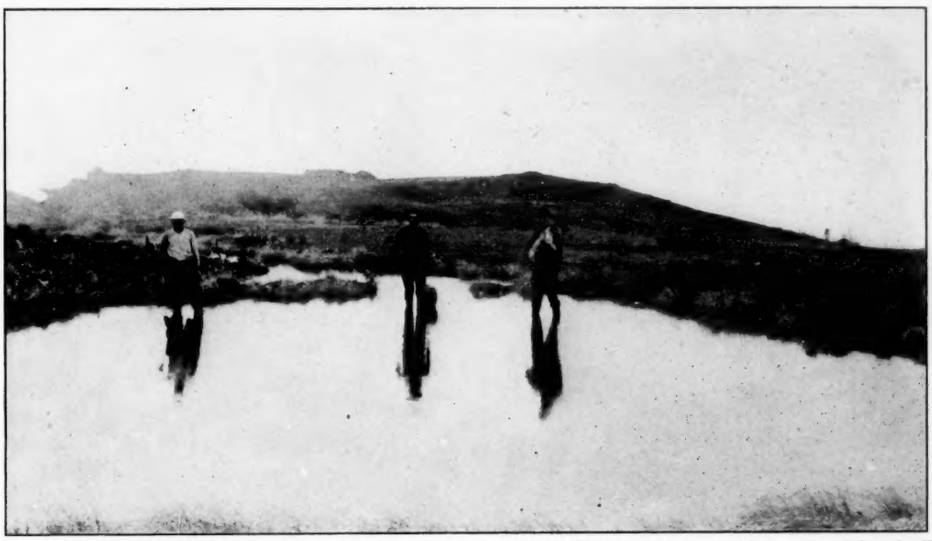

FIG. 1.—"Sacred" lake, near summit of Mount Waileale, said to have been used by ancient Hawaiians for ceremonial purposes. (Photo by W. F. Martin.)

FIG. 2.—U. S. Geological Survey topographers mapping Mount Waileale summit. (Photo by W. F. Martin.)

FIG. 3.—A U. S. Geological Survey high-level 48-inch rain gauge protected against wild cattle. (Photo by W. F. Martin.)

[To face p. 303.]

FIG. 4.—Typical upper valley spring on windward Oahu. (Photo by W. F. Martin.)

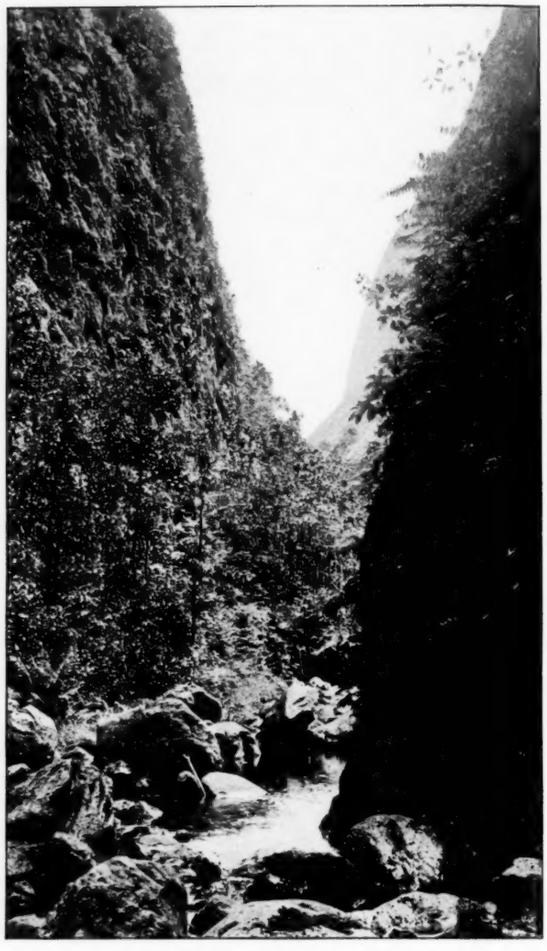

FIG. 5.—Typical mountain valley. (Note sharp topography.) (Photo by W. F. Martin.)

FIG. 6.—Typical Hawaiian mountain stream. (Photo by W. F. Martin.)

UNCLE SAM'S DAMPEST CORNER.

By G. K. LARRISON, Hydraulic Engineer, United States Geological Survey.

[Dated: Honolulu, Hawaii, May 28, 1919.]

SYNOPSIS.—It is only in recent years that the extraordinarily heavy rainfalls in portions of the Hawaiian Islands have become a matter of record. In the course of their high-level hydrometric work the engineers of the United States Geological Survey found it necessary to measure the rainfall at a number of points at various elevations up to more than 5,000 feet above sea level.

Cherrapunji, with its annual average rainfall of 426 inches, has been generally cited as the wettest place in the world. In a recent period covering nearly 5 years, Mount Waialeale, elevation 5,080 feet, on the Island of Kauai, Hawaiian Islands, averaged 476 inches of rainfall annually. In this period of 1,782 consecutive days the total precipitation was 2,325 inches—a daily average of 1.30 inches.

Another very striking feature of the rainfall records in the Hawaiian Islands is the great contrast in amounts in stations separated by only a few miles but with considerable differences in altitude or exposure. Six photographic illustrations give an excellent idea of the topography of the country while the two remaining figures show the realtive sizes of the special rain gages employed, and the mean monthly rainfall variations.—H. L.

Cherrapunji, in the Khasi Hills in India, which is said to have the greatest known annual rainfall on the earth, has a rival for the world's maximum wetness in Mount Waialeale, elevation 5,080 feet, on the Island of Kauai, Hawaiian Territory.

According to the Memoirs of the Indian Meterological Department, volume 22, 1913, the mean annual rainfall at Cherrapunji is 426 inches. The maximum precipitation is supposed to have occurred in 1861, when 905 inches was recorded, but there are grave doubts concerning the accuracy of this record.

During the periods August 2, 1911, to March 26, 1914, and May 31, 1915, to August 13, 1917, a total of 1,782 days, there was recorded on Mount Waialeale a total precipitation of 2,325 inches, or an average of 1.3047 inches per day. In a 365-day year this would amount to an annual precipitation of about 476 inches. The years of 1918 and 1914, for which, unfortunately, no records were obtained, were the wettest since the local Weather Bureau office was established in the Hawaiian Islands. Though comparative estimates are always unsatisfactory, reliable records obtained at near-by stations indicate that in both 1914 and 1918 the rainfall at this station exceeded 600 inches. From May 21, 1915, to May 30, 1916, the recorded rainfall at Mount Waialeale was 561 inches.

Mount Waialeale (figs. 1 and 2) is the peak of the island of Kauai, and is inaccessible except to the most expert mountaineers. For this reason it has been very difficult to maintain the station and it was finally discontinued on account of inability to get mountaineers to make the necessary regular visits.

There are several other damp spots in Hawaii. Puu Kukui, 5,000 feet above sea level, on the island of Maui, has for the last 7 years had an average precipitation of 369 inches, the maximum being 562 inches in 1918. On the island of Hawaii, at the intake of the Upper Hamakua irrigation ditch, 4,000 feet above sea level, rainfall amounting to 504 inches was recorded in 1914. At at least a dozen other spots—all more than 1,000 feet in elevation—in the Territory the rainfall in 1914 and 1918 exceeded 350 inches. The heaviest daily downpour ever recorded in the Territory was 31.95 inches at Honomu, Hawaii (elevation 1,200 feet), February 20, 1918.[1] According to the Weather Bureau record the total rainfall at this station for the year was 379 inches.

Except those collected at Honomu, practically all the high-level records have been obtained by engineers of the water-resources branch of the United States Geological Survey, or by parties cooperating therewith, for the local office of the Weather Bureau has been unable to collect daily records except those furnished free of cost by cooperative observers who could obtain the records at a minimum expenditure of effort. As a result nearly all the records published by the Weather Bureau are for low elevations, and as the higher levels of the Hawaiian mountains are practically uninhabited it has devolved on the Geological Survey to establish the high-level stations needed to obtain data to be used in connection with its hydrometric work. The records most needed are those for places on the upper ridges and peaks and in the upper reaches of valleys where only wild cattle and pig trails—or no trails at all—existed (fig. 3), and where no human being could possibly have set foot previous to the construction of trails by the Geological Survey.

The Hawaiian group comprises eight islands worthy of name, of which five, Kauai, Oahu, Molokai, Maui, and Hawaii have populations exceeding 1,000. The areas of these islands, in the order above named, are, 547, 598, 261, 728, and 4,015 square miles. All are characterized topographically by high central mountain ridges or peaks with many narrow precipitous valleys (figs. 4–6), as a rule flattening out to narrow plains along the seacoast. The lower slopes, saddles, and coastal plains up to levels of about 2,000 feet are usually the inhabited agricultural lands; the upper reaches are usually included in forest reserves set aside primarily to conserve and regulate stream flow. Few valleys are more than 10 or 12 miles long from ridge to costal plain, and in this distance they drop from elevations of several thousand feet to near sea level.

Except where irrigation ditches divert the valley drainage or electric-power lines cross the ridges, or where a few cattle ranches or mountain houses stand, there are few trails other than those made by wild cattle and hogs; and as a rule these trails are not adapted for human use in respect to location, overhead clearance, or foundations. In these upper valleys, also, where the rainfall is excessive and the forest cover almost of the jungle type, the soil is usually saturated and the going is very heavy. Accordingly reconnaissance work is rather strenuous, and where regular visits must be made foot trails from 3 to 8 miles long usually have to be constructed.

Of course, under these conditions, it is practically impossible to obtain daily rainfall records, and accordingly three types of raingages and an evaporation gage to measure the evaporation from the raingages (if any), to be read at monthly or longer regular periods, have been designed. The gages first installed were made of galvanized iron, but as experience proved that these would rust out in two or three years, those recently installed have been of copper.

The three types of raingages have capacities of 48, 150, and 300 inches, and the ratios of receivers to containers are 1 to 2, 1 to 5, and 1 to 10, respectively. (See fig. 7). All raingage receivers are of the standard type adopted by the United States Weather Bureau, and the top of the evaporation gage is an exact duplicate of the raingage receiver, except that the interior cone is inverted and a small cap about 2 inches in diameter is superimposed over the hole in such a way that it will keep out rain but will not prevent the effect of wind. Where it has been

[1] Cf. Table 2, p. 302.

demonstrated that there is appreciable evaporation, the raingage is never entirely emptied so that the evaporation will be continuous for the entire period between readings.

Rain and evaporation gages are "read" by merely measuring depths in containers with the ordinary reading stick used by the Weather Bureau and the actual depths, in inches, in the containers are then multiplied by the receiver-container ratios and corrections made for evaporation. An effort is made to get as many records as possible at the end of months and years, but as it is impossible with the available assistants to have all gages read on the first or last days of months and years, the readings obtained do not all furnish exact monthly or annual records, but they are usually very close approximations.

Though Hawaii may have to be satisfied with second place as to annual quantities of rainfall, it challenges the

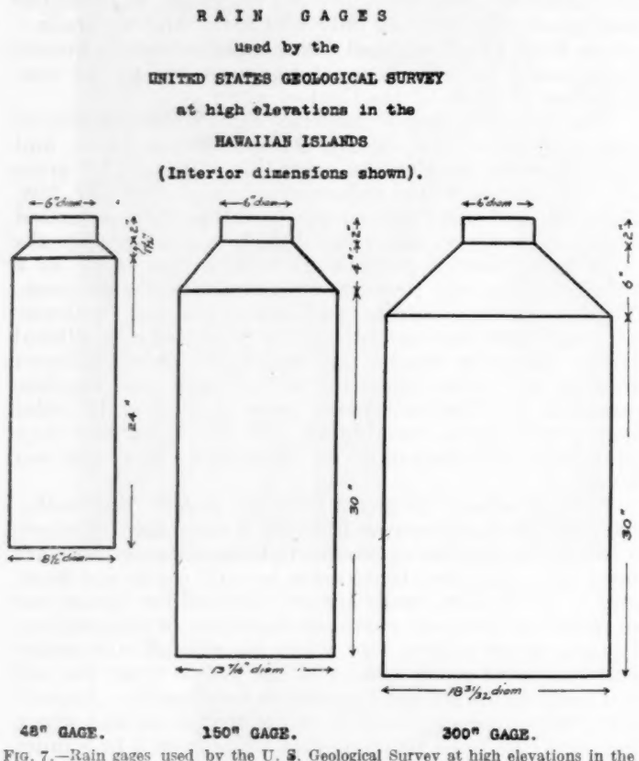

FIG. 7.—Rain gages used by the U. S. Geological Survey at high elevations in the Hawaiian Islands. (Interior dimensions are shown.)

world for variation in precipitation with vertical or horizontal distance.

Starting with Mount Waialeale, elevation 5,080 feet, on Kauai, with a mean annual precipitation of 476 inches, we have the following records, covering practically the same period.

	Elevation.	Miles.	Inches.
	Feet.		
Mount Waialeale	5,080		476
Olokele	2,100	2.0 sw.	149
Kokee	3,550	10.5 nw.	56
Pali Trail	850	11.0 sw.	16
North Wailua	650	4.0 e.	126

On Oahu likewise are wide variations. Within a radius of about 6 miles from the United States Weather Bureau central station, which is in Honolulu on the roof of the Alexander Young Building, elevation 112 feet, in the heart of the business district, and at which the annual precipitation is 31 inches, are the following stations:

	Elevation.	Miles.	Inches.
	Feet.		
Honolulu	112		31
Municipal Electric plant	405	2.5 nw.	82
Upper Luakaha	1,110	5.0 ne.	160
Puu Loa	15	6.0 w.	22

At the intake of the Wahiawa Water Co.'s ditch, elevation 1,200 feet, the mean precipitation is 231 inches; at Wahiawa village, elevation 950 feet, 5.5 miles west, the mean is only 57 inches.

On the island of Maui the variations are still more remarkable. Stations near Puu Kukui, elevation 5,000

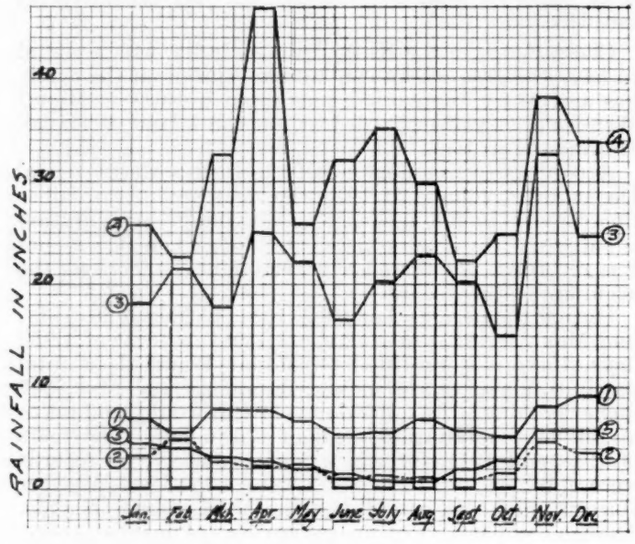

FIG. 8.—Mean monthly rainfall variations in the Hawaiian Islands. Nos. 1, 2, and 5 for 14-year period ending Dec. 31, 1918. Nos. 3 and 4 for 7-year period ending Dec. 31, 1918.

Means for Nos. 1, 2, and 5 for the 7-year period ending Dec. 31, 1918, approximately the same as for the 12-year period.
① All Weather Bureau stations on all islands.
② Weather Bureau office station, Honolulu. El. 112 feet.
③ Weather Bureau station, Honomu, Hawaii. El. 1,200 feet.
④ U. S. Geological Survey station, Puu Kukui, Maui. El. 5,000 feet.
⑤ Weather Bureau station, Seattle, Wash.

feet, with a mean of 369 inches (562 inches for 1918), give the following records:

	Elevation.	Miles.	Inches.
	Feet.		
Puu Kuki	5,000		369
Kahoma Reservoir	2,000	4.0 w.	55
Kaanapali	12	7.5 nw.	18
Wailuku village	390	5.5 se.	30

Disregarding chronology, topography, and geography, Puu Kukui, elevation 5,000 feet, during 1918 had 562 inches; at Camp No. 7 of Pioneer Mill Co., elevation 90 feet, less than 8 miles southwest, 2.47 inches was recorded in 1912.

As a rule November, December, March, and April are the wettest months, although the rule is not "hard and fast," and records are available showing just the reverse. A comparison of local records with those on the mainland northwest indicates no relation whatever in seasonal

precipitation. The graphs (fig. 8) show a fairly close relation between rainfall at Seattle and Honolulu, but the graphs for all Weather Bureau stations and for the high-level stations maintained by the United States Geological Survey in Hawaii show no such relation.

Hawaiian precipitation is also of the "showery" class, and heavy rains rarely last more than a few hours. The applicability of the general rule—that even in wet periods heavy downpours lasting a few minutes are interspersed with short periods of sunshine—varies considerably with the altitude and location. In the upper valleys, with few exceptions, showers are daily occurrences, even in dry weather, though on extreme leeward points showers are rare. On the high peaks, like Mount Waialeale and Puu Kukui, the mornings are usually clear and the afternoons and nights *very wet*.

ADDITIONAL METEOROLOGICAL DATA NEEDED BY ENGINEERS.

[Points on which more data or further study would be helpful, including rainfall distribution and intensity, precipitation and heavy floods, evaporation, vegetation, soil infiltration, temperature, run-off.]

By ROBERT E. HORTON, Consulting Hydraulic Engineer, Albany, N. Y.

[Reprinted from *Engineering News Record*, Mar. 27, 1919, pp. 614-616.]

Every experienced hydraulic engineer feels the need of additional meteorological data. First of all, there are far too few rainfall stations, and where the stations are reasonably close together group records should be studied to gain light for use where the stations are far apart. Periodic distribution of precipitation, rainfall intensities, flood flows, evaporation, the influence of vegetation, soil percolation, temperatures of the air and of the surfaces of both soil and water, and, finally, the broad general phases of run-off—all need attention. A brief review of the more important meteorological needs, grouped under 10 heads, follows:

1. *More stations.*—A much larger number of rainfall stations is needed throughout the country generally. In the East there is generally one station in each county, an average of about one station to every 1,500 square miles. In England, Denmark, Saxony, Jamaica, Barbados, St. Kitts, Victoria, and Mauritius there is an average of about one station to every 40 square miles. That is sufficient to provide good data for almost any small drainage basin, such as is commonly required for gravity water-supply systems. In New England the number of rainfall records available is about twice as great as elsewhere in the United States, owing to the fact that many good records are maintained in conjunction with water-works systems. But even in New England the number of stations is by no means adequate for satisfactory determination of the rainfall on many small drainage basins used for gravity water supply.

2. *Special group studies.*—In view of the sparsity of rainfall records, special groups of stations are needed, and studies based on existing data to determine the reliability, both of the long-term mean for any one station and the actual annual and monthly amounts indicated by single gages when applied over a varying radius of 1, 5, 10, or 15 miles from the station. Data are available at Providence, Worcester, Pawtucket, St. Louis, and New Orleans, where raingages are maintained sufficient in number to determine the general accuracy of a single record as applied to larger or smaller surrounding areas in those particular localities. Undoubtedly, with more data general relations could be established which would greatly increase the utility of rainfall records, and would also increase the degree of confidence which could be placed in such records where it becomes necessary to apply a single station to a considerable area.

3. *Periodic distribution of rainfall.*—Experience shows that with identically the same rainfall distributed in different ways throughout the year, especially during the summer, quite different amounts of run-off may result. In applying rainfall data, in critical cases, it is, therefore, necessary to take into account its distribution as well as its total amount. It is desirable, therefore, that the total number of rainfall days per month at each station should be published, with the amount of rainfall. For example: A rainfall of 4 inches in August may all occur in four days, with heavy thunderstorms, or it may be distributed throughout 10 or 20 days. In the latter case, the opportunity for water loss by evaporation would be enormously increased by the long-continued wetting of the ground surface, and the available supply for run-off would be steadier, but much smaller in amount than in the case of concentrated rainfall. I believe that practical methods can be readily developed by which the effect of rainfall distribution can be taken into account in estimating stream yield, if the number of rainfall days is known.

4. *Intensities.*—As regards rain intensity, there are at present about 200 stations in the United States with recording raingages. The details of these records, some of them running back to 1896, are published in the MONTHLY WEATHER REVIEW and in the annual reports of the Chief of the United States Weather Bureau. No complete, exhaustive analyses of all these records have ever been made. Partial analyses, covering the records within considerable areas, or for a considerable number of stations, have recently been made by Meyer and published in his "Elements of Hydrology," and by the United States Housing Corporation, the results not yet having been published. So far as the results go, they indicate that rain intensity formulas of the same type, but with varying coefficients, can be applied to localities having widely different amounts of rainfall.

Practice hitherto in using rain-intensity data in storm-sewer designing has been in general to work out a rain-intensity curve for each different place or problem. Usually, the data of the most intense and most critical storms are meager, and the results of such scattered individual studies are unquestionably less reliable than would be those obtained by thorough, general analyses involving a large number of stations of similar rainfall characteristics. There is room for much valuable work in standardizing and analyzing rain-intensity data along more general lines. Not only this, but all attempts hitherto to utilize such data have been wholly empirical. There is reason to believe that at least a semi-rational formula of general application can be developed for rain intensities of short durations.

5. *Great storms and floods.*—In connection with the broader problems of flood causation and flood discharge, studies of rain intensity in great storms covering periods of one to five days are needed. A valuable start was made in this direction by the Miami Conservancy District, the results being given in its series of technical reports, part 5. Good work along similar lines, with much more numerous records on which to base the results, has been done by the British Rainfall Organization.

One of the most fundamental problems of flood control is the determination of the relative frequency of occurrence of floods of different magnitudes, as fixing the

maximum size and cost of works economically justified for flood control. Further data and analyses along these lines are much needed, and would be likely to afford results of broad utility and permanent value.

It may be noted in passing that so far as the studies by the Miami Conservancy District go, they seem to indicate that the law covering the relative magnitudes of storms of one to five days' duration, and having different intensities and frequencies of occurrence, is very similar in form to the general law covering the relations between frequency, intensity, and duration of short storms, such as are involved in storm-sewer designing—with, however, probably, the important difference that temporary storage of considerable volumes of rain by suspension in the upper air, in ascending air currents, is the important factor contributing to high intensities for rainfall duration of less than, say, one hour, but is not of importance in relation to storms of one or more days' duration.

Incidentally, there is a gap between existing results of studies covering, on the one hand, rain intensities used in storm-sewer designing and of generally less than one hour's duration, and flood intensities of one or more days' duration. This seems to open up a profitable field for investigation—a field which would be very likely to lead to results useful in both classes of studies. Furthermore, in many flood problems and in numerous litigations involving rainfall, the only data available are daily rainfall records. Data and studies showing the relation between 24 hours' rain and the average duration and intensity for the actual portion of the day during which rain fell are much needed.

6. *Evaporation.*—With regard to evaporation, very good records are now being kept by the Weather Bureau and other Government organizations. It appears, however, that records obtained from the ordinary evaporation pan, say 3 feet square, are not directly applicable to broad water surfaces. There is need for experimental determination of what may be called the area factor or average ratio of evaporation loss from a standard pan of a certain size to the evaporation loss from an area of any given size larger or smaller. A start along this line has been made in the work of Prof. F. H. Bigelow, R. B. Sleight, and others.

The writer, in Engineering News-Record of April 26, 1917, page 196, has called attention to the physical factors underlying and controlling this so-called area factor. The area factor involves, however, certain climatic conditions, especially convective action, data for which are not included in meterological reports. In view of the complexity of the subject, further studies, especially out-of-door experiments with evaporation pans of various sizes, are greatly needed.

In this connection, too, attention may be called to the need of further data and studies on the relation of altitude to evaporation. There is a prevailing popular notion that evaporation increases with elevation. This idea is undoubtedly derived from the well-known fact that water boils more readily at high than at low altitudes. This, however, is only one of the elements involved. Mean temperature at the surface decreases on the average about 1° for 300 feet elevation. The absolute humidity also decreases with elevation, in accordance with the exponential law developed by Hann. Wind velocity generally tends to increase with increased elevation. The amount of evaporation from water surfaces is mainly controlled by temperature, humidity, and wind velocity, and is affected probably to a minor extent by other factors, including so-called radiation or black-bulb thermometer temperatures, facility for convection, and barometric pressure. Some of the factors tend to cause an increase and others tend to cause a decrease in the amount of evaporation with increasing altitudes. The natural result would be the occurrence of some particular elevation for which evaporation losses would be [at a] maximum. While this fact never seems to have been pointed out before, yet it is confirmed by the few good observations available, especially those of Charles H. Lee. The whole subject of relation of evaporation loss to elevation is worthy of further investigation and more rational discussion.

7. *Vegetation.*—The subject of interception of rainfall by vegetation will be seen to be one of great importance, when it is considered that oftentimes, especially in light showers, 50 per cent or more of the rain is caught upon and directly evaporated from trees or other vegetation and never reaches the ground. This subject has been experimented upon in Europe, and to a limited extent in United States by the writer, and, I believe, also by the United States Weather Bureau. Further investigation and discussion would aid in laying a foundation for more rational estimates of stream flow and better determinations of water requirements for irrigation purposes.

8. *Infiltration.*—Floods are mainly the results of direct surface run-off from heavy rains or melting snows. The direct evaporation loss during flood rains is usually only a very small proportion of the available supply of water. The difference in flood-discharging capacities of different drainage areas is, without doubt, more largely due to differences in the amount of water which can percolate into the soil during heavy rains than to any other one factor excepting rainfall itself.

Furthermore, infiltration of rainfall is the source of ground-water supply to streams, wells, and artesian horizons; yet, with the exception of some meager experiments by O'Meara and the writer, practically nothing has been done in this country relative to the determination of the amount of infiltration into different soils, on different slopes, and with different rates of rainfall. Numerous formulas for estimating maximum flood discharges have been evolved, but it does not seem possible to arrive at either a rational understanding of the causation of floods or the most reliable method of estimating probable maximum flood discharge without taking into account the amount of infiltration occurring during rains.

9. *Temperature.*—The most important factor affecting evaporation losses of all kinds is temperature It is also an important factor in relation to floods as affecting the rate of melting of accumulated snow. Data for air temperature are generally available, but what is needed in relation to evaporation is the temperature of the soil and of water surfaces. Data on these subjects are meager. The obtaining and publishing of additional data of soil-surface and water-surface temperatures, and especially the correlation of such temperatures with air temperature, are matters which will become of increasing importance and value as the development and use of more rational methods of handling hydrologic problems progress.

10. *Run-off.*—The run-off or yield of a drainage basin is the difference between the precipitation on the drainage basin and the water losses due to evaporation of various kinds. The amount of evaporation from the soil surface is dependent upon the same factors which control evaporation from water surface and, in addition, it is dependent on the degree of saturation of the soil surface. Some experimental data in relation to the evaporation loss from soil surface with different degrees

of saturation have been obtained by Samuel Fortier (see Engineering Record of April 15, 1905, p. 430).

Additional experimental data along this line would be of the utmost practical and economic value, not only in relation to the ordinary problems of hydrology in estimating stream flow, but also in relation to irrigation, land drainage, and agricultural engineering in general. The writer has designated the ratio of the actual evaporation rate from a soil surface at any given time and with any degree of saturation to the evaporation rate from water or a saturated soil surface as the "evaporation opportunity."[1]

It so happens that in long periods of drought, when the evaporation rate from a saturated surface is highest, the evaporation opportunity from the soil surface decreases. It is a natural result of these opposing influences that there is some particular amount and distribution of rainfall in any locality for which the total evaporation loss from the soil is a maximum. Although this is important, the writer does not think that it has ever hitherto been pointed out. Strangely enough, it follows as a simple mathematical deduction from a number of existing formulas for calculating run-off and, furthermore, it is abundantly confirmed by experience, inasmuch as it will be found that if almost any long-term record of rainfall and stream flow is analyzed, and the results are plotted in terms of water losses against precipitation, the resulting water losses will have a maximum for an annual rainfall which generally lies between 45 and 75 inches in England and the eastern United States.

This calls attention to the fact that the older ideas and methods of expressing run-off as a percentage of rainfall are essentially fallacious, and if engineers are to justify public confidence with regard to their ability to predict safely the available yield of water-supplies, their work must, in the future, be founded upon the use of meterologic data now often ignored and upon more rational and detailed methods of analyzing and utilizing such data.

[1] "Relative evaporation" or "Evaporativity" might be a more suggestive designation. See MONTHLY WEATHER REVIEW, Jan. 1919, 47:30.—EDIT.

ELEMENTS OF HYDROLOGY.

By ADOLPH F. MEYER, C. E., Associate Professor of Hydraulic Engineering, University of Minnesota.

[John Wiley & Sons (Inc.), New York, 1917, pp. 487, 287 figs.]

This volume is a welcome addition to our knowledge of hydrology and its practical application. It was prepared for the use of professional men, teachers and students of engineering, and aims to set forth the fundamental data and considerations rather than to provide a text book.

After defining hydrology and its applications the author presents in Chapter II a résumé of the physical properties of the atmosphere with a more or less condensed account of the variations of the several meteorological elements, closing with a brief reference to the general circulation of the atmosphere as manifested in the winds. Chapter III is devoted to a consideration of water, its various states and properties. Chapter IV on precipitation is a very complete résumé of the essential facts concerning the occurrence of precipitation and its geographic distribution. The remaining chapters deal with evaporation, from land and water surfaces transpiration, deep seepage, run-off, stream-flow data, supplementary stream-flow data, and modification of stream flow by storage.

The book is unusually rich in illustrative material, drawn largely from Federal and State reports, from private sources, as well as from the author's original investigations.—*A. J. H.*

THE WEATHER AND DAILY STREAM FLOW FOR HYDRO-ELECTRIC PLANTS.

By J. CECIL ALTER, Meteorologist.

[Dated: Weather Bureau, Salt Lake City, Utah, Apr. 11, 1919.]

SYNOPSIS.—The important part played by daily weather forecasts in the problem of water regulation for hydroelectric plants in Utah is brought out in this paper. The writer compares this work with the daily prediction of water stages on eastern rivers. As many of the hydro-electric plant reservoirs are located at least 36 hours' travel (measured by stream flow) from the plants themselves, it is of great importance that weather conditions, particularly as regards precipitation, be accurately known 36 hours in advance. If, for example, rain is expected at the end of any given period of 36 hours the reservoir outlet can be closed and the precious water saved until needed. On the other hand, if a period of dry weather is expected to set in at the end of 36 hours, the outlet at the reservoir must be opened so that the plant will have an abundance of water. These conditions apply equally well to irrigation control.—H. L.

Daily weather forecasts and general meteorological data have for some time entered rather largely into the problem of water regulation for the 27 hydro-electric plants of the Utah Power & Light Co., in northern Utah, and southeastern Idaho, as managed by Maj. Cooper Anderson, superintendent of the power department. The general problem bears some analogy to the daily prediction of water stages on eastern rivers, but many additional factors require serious consideration.

All but four of the plants mentioned are located on the smaller streams coming out of the Wasatch Mountains, the flow of which can be relied upon for running the plants to machine capacity only in the flood time; this is from about March to early June, inclusive, when mountain snow is melting most rapidly, and when precipitation is normally heaviest. During the remainder of the year many of these plants are subject to greatly decreased output for want of water.

In summer and autumn the water supply from snow stores in the mountains reaches a minimum, and this is normally the period of lightest precipitation in this region. A sustained stream flow, ample for power production purposes, occurs in these months only when previous snowfall and current precipitation are abnormally heavy. In winter the tributaries are closed by ice with the first hard freeze, the frost gradually sealing the larger feeders, and finally the trunk stream if the weather be very severe.

It is essential that these scattering plants be operated as fully as possible, because of their nearness and convenience to purchasers of the power produced; and inasmuch as the company provides by far the greater percentage of all electricity used by the mining, smelting, interurban and street railway, sugar refining, city lighting, and other companies in this district, which includes Salt Lake City, Ogden, and probably a score of smaller towns, the demands for current are very exacting.

However, by an extensive network of transmission lines throughout the region, any one plant or series of plants may be closed down, and its customers supplied without interruption of service by other plants. In fact, since so much depends on the elements in critical seasons provision is made for the emergency closing of more than one-half the smaller plants, in the installation of four mammoth plants on Bear River, the largest stream in the region, which have a production capacity of about 70 per cent of the average requirements of the entire system.

This stream is much more dependable, by reason of its length and size, than the smaller streams; but like all streams dependent on mountain snowfall, its spring freshet curve is followed by a serious decline. Therefore Bear Lake, a large body of water on the Utah-Idaho boundary, has been made to serve as a storage reservoir, though it is situated about 75 miles from the nearest of the large plants, at Grace, Idaho; 80 miles from the Cove plant; 100 miles from the Oneida plant; and about 170 miles, as the stream flows, from Wheelon, Utah, the farthest of the "Big Four." (Fig. 1.)

Under the most favorable conditions it requires at least 30 hours for water from the lake to reach the nearest plant

FIG. 1.

at Grace, and it very frequently requires as much as 48 hours of flowing time. In winter, when there is loose ice, slush, snow, or any considerable blockading from any cause, the flowing time is much greater still. The flowing time to Wheelon is practically double that to Grace. Only the plant at Oneida has a small auxiliary storage reservoir, the rest being solely dependent on the stream flow.

"Thus it will be seen," according to G. I. McFarland, superintendent of the Grace plant, "that every move made in the regulation of water is based absolutely on predictions of conditions that will obtain 36 hours later." And according to Chief Dispatcher H. S. Buchanan, the prediction of weather conditions and factors affecting stream height, as well as the demands for power from the various plants, must always be foreseen over as great a period of time as possible.

The utilization of water above the plants for irrigation in summer varies greatly from day to day with the general weather conditions and with the stages of the crops. Heavy showers will give a certain increase in the flow of streams from the immediate watersheds affected within a certain length of time and for a certain duration, and if the showers be sufficiently heavy in the agricultural regions there will be less irrigation water used for a few days after the storm. The problem of water regulation for power purposes varies also with the geographical distribution and the amount of precipitation from such storms. On the other hand, spells of dry, hot weather increase the demands for irrigation water and deplete the available supply correspondingly.

Numerous weather stations are maintained by the company, some of them having the status of cooperative stations of the Weather Bureau, from which reports are compiled daily in the central offices of the company at Salt Lake City for direct application to the problem of water regulation. Daily measurements of the flow of Bear River and of important irrigation canals near the lake and the Grace plant are made and dispatched to the power department, and once a week the discharge of all tributaries and irrigation canals between the lake and Grace is measured for correlation with all other conditions affecting the flow.

The company thus knows approximately from day to day how much water is available, how much power it will produce, and whether the water supply is increasing or decreasing. By July 1 the decreasing flow of all streams makes it necessary to release the flow from Bear Lake, through gravity outlets and later by pumping, to supply the gradually increasing demands on the Bear River plants. However, this water is extremely precious in dry seasons—and no one can foresee definitely that the coming few months will not be otherwise—hence it is doled out as economically as possible, withholding every foot that is not certain to be needed, a regulation which during the month of July, 1918, was so carefully applied that less than one-half of 1 per cent of the flow was wasted over the spillway at Grace.

Each day the chief dispatcher and the superintendent of power determine from the load carried the day before and the demands for power on the day following, with the weather and water conditions over the system, just what redistribution of electricity production in the various plants must be made, and particularly how much of the load is to be carried by the Bear River plants. This means in turn the determination of the amount of water to be released from Bear Lake, always remembering that the lake is from 30 to 48 hours distant, measured by the stream flow.

In winter a very troublesome condition is that of mush-ice formation, which is produced in very cold weather as the water passes over the many stony rapids. This congealed but unsolidified water lodges very readily against every obstacle and forms more or less extensive blockades here and there in the rougher parts of the stream. Such conditions must not only be anticipated, but must be quickly located and removed when formed. Usually the only means of removing such accumulations is by hydraulic pressure, produced by a crest of flood water from the lake, and this is often a slow process and results at times in field flooding.

Anchor ice, which forms in extremely cold weather on all protruding rocks and other objects where waves, splashing, or spray reaches is also very troublesome and may form a very effectual jam that is hard to dislodge. A heavy snowstorm tends to slow down the rate of stream flow, if it does not prove sufficient to produce a condition similar to mush ice. If the stream becomes well frozen over and a fairly constant discharge can be maintained, there is very little open water (only in the rapids), and consequently little trouble occurs until the ice goes out. It is sure to go out with more or less clogging in springtime, if not in a winter thaw, but a winter rain, not

attended by sufficient duration of warmth to thaw the ice, is even more disastrous, unless the flow can be regulated to allow all water to pass under the ice.

The daily publications and reports of the Weather Bureau, especially the forecasts, are utilized freely in the consideration of this daily problem of water regulation, the superintendent of power having made intensive use of the weather map until it was suspended during the war, in amplifying the general forecasts for the specific problems in his own region. During the past winter (December, 1918, to March, 1919, inclusive) the State forecasts were amplified at the Salt Lake City office of the Bureau for the Bear River region, and the conditions prevailing over the northwestern States were given to the officials of the company by telephone each morning for their consideration in the water regulation problem.

THE COLORADO RIVER.

By FREDERICK H. BRANDENBURG, District Forecaster.

[Dated: Weather Bureau, Denver, Colo., July, 1916.]

SYNOPSIS.—This paper concerns the method of river-stage forecasting for the Colorado River and its principal tributaries, the Green, Grand, and San Juan Rivers. A brief description of the topographic features and courses of these streams is given. Attention is given to temperature conditions, as these to a large extent control the melting of the snows, which in turn make up much of the water supply. Two rating tables supplement the text, covering the Green and the Grand Rivers, respectively.—H. L.

The Colorado River is formed by the junction, in southeastern Utah, of the Green and Grand Rivers, and is joined by the San Juan River, its most important tributary, a few miles north of the Arizona-Utah State line. (See Fig. 1.)

The Green River rises in the mountains of southwestern Wyoming, and thence flows southward. From its source to its junction with the Grand River the Green is 425 miles in length. Near the Colorado-Utah State line it receives the waters of the Yampa and White Rivers, which drain northwestern Colorado.

The Grand River, which rises on the western slope of the Continental Divide in central Colorado, is joined by the Gunnison River at Grand Junction, Colo., and also by the Dolores, which drains the western slope of the San Juan Mountains, a short distance above the junction of the Grand and Green Rivers.

The San Juan, which rises on the southern slope of the San Juan Mountains, a part of the Continental Divide in southwestern Colorado, is about 200 miles in length.

In southeastern Utah and northern Arizona the Colorado River flows in a deep, rocky gorge, or canyon, through a region practically uninhabited, and the conditions are very similar along the Green and Grand Rivers for about 125 miles above their junction.

The drainage area of the Colorado River falls naturally into three divisions, the low-lying desert region, the elevated plateau region, and the mountain region. Each division has its characteristic climatic features. The lower division extends from the Gulf of California to the most easterly part of southeastern Nevada; the middle division from southeastern Nevada to the rating stations at Elgin, Utah; Fruita, Colo.; and Farmington, N. Mex.; and the upper division includes the area above such stations. The upper division is bordered on the north and east by the Continental Divide and on the west by ranges of high mountains.

The main flow of the Colorado comes, of course, from the snowfall in its upper reaches. The flow, however, is seldom large except during the periods of melting of the snow in the mountains. The summer rise usually occurs in June. The middle division contributes a considerable volume of water during March, April, and often during the first half of May from the melting of snow on the high table-lands. Practically no flow is received from snowfall in the lower division, although in the northern part of that division there are mountains which rise to an altitude of several thousand feet.

The mountainous nature of the country and the lack of telephone and telegraph facilities prevent the establishment of gaging stations on any part of the upper Colorado River. The usual method of predicting stages from gage readings at upstream stations on the same river is therefore out of the question, and results as unsatisfactory almost invariably attend an attempt to predict the stages of water on the main river from gage heights on the three rivers uniting to form it because they are so widely separated and their flow varies so greatly, a different method of arriving at results is necessary.

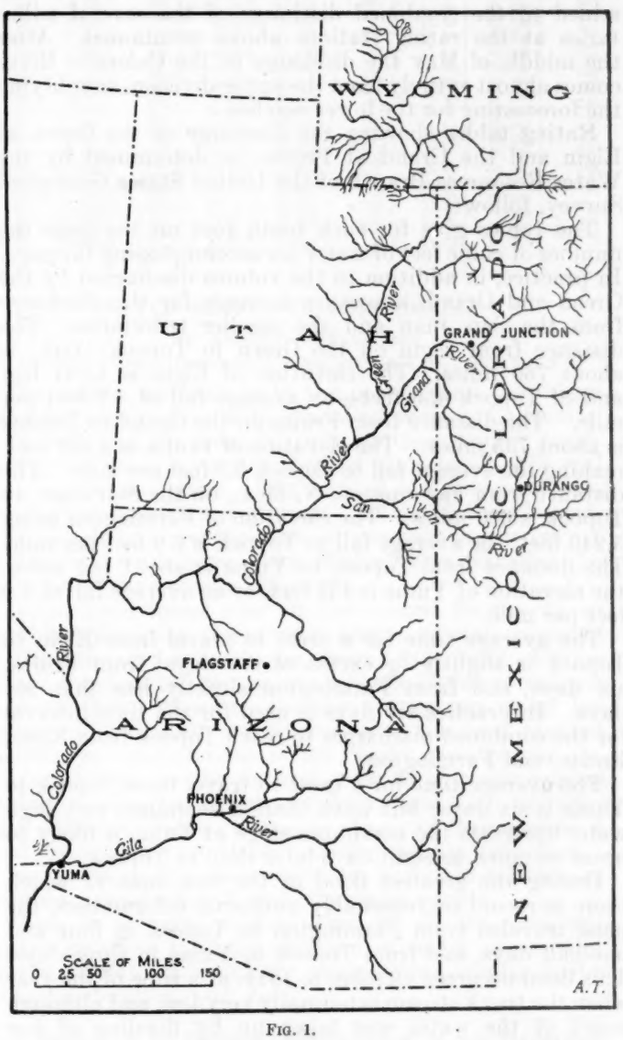

FIG. 1.

Temperature conditions as affected by different altitudes and the wide range in latitude through which the Colorado River and its tributaries flow control the melting of snow and affect the rate and date of the rise and the volume of water discharged. One tributary may be low, while the others are high at a corresponding time; another year the conditions may be directly the opposite. By combining the discharge the volume in cubic feet per second is the same as though the entire discharge were in one stream. Discharge measurements are made in the Grand River at Fruita, Colo., a few miles below the junction of the Grand and Gunnison; and on the Green River at Elgin, Utah. The discharge of the San Juan is estimated from the gage heights at a station near Farmington, N. Mex.

Usually there is an early and moderate crest in the lower trunk stream from the melting of snow in the middle division. As this area is below the rating stations, an estimate of the amount of this flow must be made and added to the combined discharge of the several tributaries at the rating stations above mentioned. After the middle of May the discharge of the Colorado River comes almost entirely from the upper division, simplifying the forecasting for the lower reaches.

Rating tables showing the discharge of the Green at Elgin and the Grand at Fruita, as determined by the Water Resources Branch of the United States Geological Survey, follow:

The tables give for each tenth foot on the gage the number of cubic feet of water per second passing the gage. In practice, in addition to the volume discharged by the Green and Grand, allowance is made for the discharge from the San Juan and the smaller tributaries. The distance from Elgin on the Green to Topock, Ariz., is about 760 miles. The elevation of Elgin is 4,044 feet and of Topock 456 feet—an average fall of 4.7 feet per mile. The distance from Fruita on the Grand to Topock is about 735 miles. The elevation of Fruita is 4,487 feet, making the average fall to Topock 5.5 feet per mile. The distance from Farmington, N. Mex., on the San Juan, to Topock is 690 miles. The elevation of Farmington being 5,240 feet, the average fall to Topock is 6.9 feet per mile. The distance from Topock to Yuma is about 165 miles; the elevation of Yuma is 137 feet, or an average fall of 1.9 feet per mile.

The average time for a crest to travel from Elgin to Topock is slightly in excess of six days; from Fruita, six days; and from Farmington slightly less than six days. In practice six days is used for the time interval for the combined discharges to reach Topock from Elgin, Fruita, and Farmington.

The average time for a crest to travel from Topock to Yuma is six days; but when there is sustained very high water upstream the maximum stage at Yuma is likely to occur as much as eight days later than at Topock.

During the greatest flood in the San Juan of which there is record or reasonably authentic information, the peak traveled from Farmington to Topock in four and one-half days, and from Topock to Yuma in three days. This flood occurred October 6, 1911, at a time of the year when the trunk stream is normally very low, and although much of the water was taken up by flooding of low ground adjacent to the river, the time interval was appreciably shorter than during the summer rises.

FORECASTING HIGH STAGES IN THE COLORADO RIVER.

Flood waves as commonly understood are the result of heavy rains. Heavy, general rains are unknown on the Green watershed, while heavy rains on the Grand watershed are local in character and unusual. The mountain region draining into the San Juan, however, is occasionally subjected to heavy downpours, causing destructive freshets. The bed of the main river can accommodate the largest freshets that occur in the Green, the Grand, or the San Juan singly, but when two of these rivers are in flood at the same time the lower river below the point of junction overflows its banks and causes damage. This condition occurs only as the result of the melting of heavy and general snowfall in the upper reaches.

Occasionally the measured discharge of the Colorado River at Yuma is less than the aggregate discharge of its tributaries at the gaging stations heretofore mentioned. The difference is in part due to the diversion of water for agricultural purposes under the Yuma reclamation project. As the maximum amount of these diversions is only about 6,000 second-feet, the cause of the smaller flow is most likely due to the temporary holding of the flood waters on the lowlands adjacent to the river, which are slow to return.

The time interval for crests increases with the flooding of the lowlands. Flood plains cover a large area in the lower division. For miles above the station at Topock the valley is 5 or 6 miles wide, and during freshets much of this area is covered by water, the overflow beginning when the gage at Topock is 11.5 feet; and when at 17 feet the river at Needles, Cal., 11 miles upstream, is 3 or 4 miles wide.

Another factor to be taken into account when forecasting river gage heights of the lower river is whether the season under consideration follows a year or two free from freshets. During prolonged periods of comparatively low stages of the water, the immense amount of silt brought down from the upper reaches, where the fall is great and the current swift, is deposited in the bed of the lower river where the gradient does not exceed 2 feet to the mile and the current is correspondingly sluggish. Under this condition the same volume of water causes a higher stage than it would if it had been preceded by a freshet during the same or even the preceding year. Scouring is rapid when the water is high. During the freshet of 1909 it is said the channel at Yuma was temporarily deepened 40 feet.

The following general principles are fairly well established:

The relation between the volume discharged and gage heights is close in extreme crests.

The time interval from the tributaries to the lower river is practically the same in extreme crests.

There is a flattening out of freshet waves before the lower river is reached.

The general rules which in practice have controlled forecasting of the stages of water in the lower reaches of the Colorado are as follows:

1. Expected gage heights at lower stations produced by combined discharge at rating stations above, have been determined.

2. Correction must be made for capacity of channel as affected by previous or absence of previous freshets, and also for amount of water likely to be contributed by the middle division.

3. The relation between gage readings and discharge at the rating stations above on the one hand, and the actual gage readings at the stations below on the other, as ascertained during the last preceding crest, deter-

mines the basis for the correction from the normal to be allowed.

4. The difference, if any, during the last preceding crest, between actual gage heights at lower stations and the expected heights at such stations must be considered and an allowance, corresponding to such difference, if any, made in the forecast.

5. If the combined discharge of the Grand, Green, and San Juan is in excess of 120,000 second-feet the time interval from these stations is one day longer for the crest at Topock and two days for the crest at Yuma.

6. There is generally a heavy run-off from the middle division before active melting sets in in the upper division, and accordingly from 10,000 to 20,000 second-feet are added to the upstream discharge in April and the early part of May, the amount depending on the preceding season's snowfall.

7. The time interval from the middle division to the stations in the lower division is four or five days.

8. When one crest follows another, the intervening period being too short for the submerged lands to drain, the time interval from the upper division to the lower division is reduced one or two days.

FALLING RIVER.

When falling stages occur in the upper reaches they are due to cooler weather or to the fact that the season's maximum of melting of snow has passed. The lower river falls rapidly as soon as the crest has passed. It is not unusual for the decline to equal 30,000 second-feet the first day and 20,000 second-feet the second and third days.

TABLE 1.—*Rating table*[1] *for Green River at Elgin, Utah, near Green River, Utah.*

Gage height.	Discharge.	Difference.	Gage height.	Discharge.	Difference.	Gage height.	Discharge.	Difference.
Feet.	*Sec.-ft.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Sec.-ft.*
6.00	3,300	300	9.40	18,900	600	12.80	43,600	800
6.10	3,600	300	9.50	19,500	600	12.90	44,400	800
6.20	3,900	300	9.60	20,100	600	13.00	45,200	800
6.30	4,200	300	9.70	20,700	600	13.10	46,000	800
6.40	4,500	300	9.80	21,300	600	13.20	46,800	800
6.50	4,800	300	9.90	21,900	700	13.30	47,600	800
6.60	5,100	320	10.00	22,600	700	13.40	48,400	800
6.70	5,420	340	10.10	23,300	700	13.50	49,200	800
6.80	5,760	360	10.20	24,000	700	13.60	50,000	800
6.90	6,120	380	10.30	24,700	700	13.70	50,800	800
7.00	6,500	400	10.40	25,400	700	13.80	51,600	800
7.10	6,900	420	10.50	26,100	700	13.90	52,400	800
7.20	7,320	420	10.60	26,800	700	14.00	53,200	800
7.30	7,740	440	10.70	27,500	700	14.10	54,000	800
7.40	8,180	440	10.80	28,200	700	14.20	54,800	800
7.50	8,620	460	10.90	28,900	700	14.30	55,600	800
7.60	9,080	460	11.00	29,600	700	14.40	56,400	800
7.70	9,540	460	11.10	30,300	700	14.50	57,200	800
7.80	10,000	500	11.20	31,000	700	14.60	58,000	800
7.90	10,500	500	11.30	31,700	700	14.70	58,800	800
8.00	11,000	500	11.40	32,400	800	14.80	59,600	800
8.10	11,500	500	11.50	33,200	800	14.90	60,400	800
8.20	12,000	500	11.60	34,000	800	15.00	61,200	800
8.30	12,500	500	11.70	34,800	800	15.10	62,000	800
8.40	13,000	500	11.80	35,600	800	15.20	62,800	800
8.50	13,500	600	11.90	36,400	800	15.30	63,600	800
8.60	14,100	600	12.00	37,200	800	15.40	64,400	800
8.70	14,700	600	12.10	38,000	800	15.50	65,200	800
8.80	15,300	600	12.20	38,800	800	15.60	66,000	800
8.90	15,900	600	12.30	39,600	800	15.70	66,800	800
9.00	16,500	600	12.40	40,400	800	15.80	67,600	800
9.10	17,100	600	12.50	41,200	800	15.90	68,400	
9.20	17,700	600	12.60	42,000	800			
9.30	18,300	600	12.70	42,800	800			

[1] The above table is not applicable for ice or obstructed channel conditions. It is based on three discharge measurements made during 1910 and the form of previous curves; one discharge measurement being made June 13, 1909, gage 15.15 feet, and is not well defined.

125518—19——3

TABLE 2.—*Rating table for Grand River near Fruita, Colo.*

Gage height.	Discharge.	Difference.	Gage height.	Discharge.	Difference.	Gage height.	Discharge.	Difference.
Feet.	*Sec.-ft.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Sec.-ft.*
3.00	3,010	140	7.00	12,400	350	11.00	34,500	720
3.10	3,150	150	7.10	12,750	360	11.10	35,220	720
3.20	3,300	150	7.20	13,110	360	11.20	35,940	720
3.30	3,450	160	7.30	13,470	360	11.30	36,660	720
3.40	3,610	160	7.40	13,830	360	11.40	37,380	720
3.50	3,770	170	7.50	14,200	400	11.50	38,100	740
3.60	3,940	170	7.60	14,600	420	11.60	38,840	740
3.70	4,110	180	7.70	15,020	440	11.70	39,580	740
3.80	4,290	180	7.80	15,460	460	11.80	40,320	740
3.90	4,470	190	7.90	15,920	480	11.90	41,060	740
4.00	4,660	190	8.00	16,400	480	12.00	41,800	740
4.10	4,850	200	8.10	16,880	500	12.10	42,540	740
4.20	5,050	200	8.20	17,380	500	12.20	43,280	740
4.30	5,250	200	8.30	17,880	520	12.30	44,020	740
4.40	5,450	210	8.40	18,400	520	12.40	44,760	740
4.50	5,660	210	8.50	18,920	520	12.50	45,500	740
4.60	5,870	210	8.60	19,440	520	12.60	46,240	740
4.70	6,080	220	8.70	19,960	540	12.70	46,980	740
4.80	6,300	220	8.80	20,500	540	12.80	47,720	740
4.90	6,520	220	8.90	21,040	540	12.90	48,460	740
5.00	6,740	230	9.00	21,580	560	13.00	49,200	740
5.10	6,970	230	9.10	22,140	560	13.10	49,940	740
5.20	7,200	230	9.20	22,700	580	13.20	50,680	740
5.30	7,430	240	9.30	23,280	580	13.30	51,420	740
5.40	7,670	240	9.40	23,860	600	13.40	52,160	740
5.50	7,910	250	9.50	24,460	600	13.50	52,900	740
5.60	8,160	250	9.60	25,060	620	13.60	53,640	740
5.70	8,410	260	9.70	25,680	620	13.70	54,380	740
5.80	8,670	260	9.80	26,300	640	13.80	55,120	740
5.90	8,930	270	9.90	26,940	640	13.90	55,860	740
6.00	9,200	280	10.00	27,580	660	14.00	56,600	740
6.10	9,480	290	10.10	28,240	660	14.10	57,340	740
6.20	9,770	300	10.20	28,900	680	14.20	58,080	740
6.30	10,070	310	10.30	29,580	680	14.30	58,820	740
6.40	10,380	320	10.40	30,260	700	14.40	59,560	740
6.50	10,700	330	10.50	30,960	700	14.50	60,300	740
6.60	11,030	330	10.60	31,660	700	14.60	61,040	740
6.70	11,360	340	10.70	32,360	700	14.70	61,780	740
6.80	11,700	350	10.80	33,060	720	14.80	62,520	740
6.90	12,050	350	10.90	33,780	720	14.90	63,260	

WATER SUPPLY IN CALIFORNIA.

By ANDREW H. PALMER.

[Abstract: Journal of Geography, New York, Vol. xviii, No. 2 (Feb., 1919.)]

The author discusses both the present and the future water supply problem, with special reference to California.

The effect of the great latitude and topographic variation in the State is very marked on the rainfall—the real source of water power. The rainfall of California[1] presents some astounding contrasts. In the Mohave Desert, for example, the average annual precipitation is only 1 to 2 inches, while in portions of the Sierra Nevadas the annual amount exceeds 100 inches.

It has been found that in the central Sierras up to 5,000 feet elevation the average annual rainfall increases at the rate of 8.5 inches for each 1,000 feet.[2] Fortunately, much of the precipitation at the higher elevations is in the form of snow, thereby storing up water for power and irrigation purposes during the long rainless summers so characteristic of the Pacific coast States.

After taking up the natural controls of water power, namely, climate, topography, geology, vegetation, and artificial agencies (dams, reservoirs, etc.), the writer gives a brief history of hydro-electric development in California.

In conclusion, he discusses water power in relation to irrigation, flood control, and city water supply.

Thus, it is quite evident that of all the principal factors entering into the problem of water power and supply, climate, particularly precipitation, demands the first consideration.—*H. L.*

[1] *See* McAdie, A. G., The Rainfall of California, Univ. of Cal. pubs. in Geography, Berkeley, Calif., vol. 1, No. 4, February, 1914.

[2] Henry, A. J.: Increase of precipitation with altitude, MONTHLY WEATHER REVIEW, January, 1919, 47: 33–41. (2 figs.)

TEMPERATURE INFLUENCE ON PLANTING AND HARVEST DATES.

By JOSEPH B. KINCER, Meteorologist.

[Dated: Weather Bureau, Washington, Feb. 15, 1919.]

SYNOPSIS.—(1) There are certain restricted limits of time within which crops must be planted for best results, defined by the temperature conditions of the locality. The length of the time period within which the planting of a given crop may be accomplished decreases in general with increase in latitude.

(2) A definite amount of heat is required after planting to bring a crop to maturity; as a rough measure of this the accumulated day-degrees of temperature above the mean temperature at which planting is accomplished, may be taken. As thus computed there is very little difference in the amount of heat necessary to mature most staple spring planted crops, when the average variety of corn is considered. It is suggested that the mean temperature at which the planting of a given crop can be accomplished be used as a base, or starting point, for any method that may be employed for temperature summation, instead of a general base for all crops. If the frequently used 6° C. base be employed in the case of cotton, for example, we would begin the reckoning of effective temperatures in the vicinity of Abilene, Tex., about three months before planting can begin, with a resulting indicated large accumulation of effective temperature before any growth is possible.

(3) Spring wheat seeding begins with a lower mean temperature than any other major spring crop. Seeding usually begins in the Dakotas and in Nebraska when the normal daily temperature rises to 37° (F.) and in Minnesota and Wisconsin when 40° (F.) is reached. Next in thermal order comes spring oats, the seeding of which usually begins when the normal daily temperature rises to 43° (F.) (corresponding to the advent of the vegetative period). Early potato planting begins as a rule when the normal daily temperature rises to 45° (F.), and corn when 55° (F.) is reached. The dates on which the latter is reached correspond closely to the average dates of last killing frost in spring. Cotton planting usually does not begin until the normal daily temperature rises to about 62° (F.). The dates on which this temperature is reached correspond closely to the latest dates in spring on which killing frost has occurred.

(4) Cotton and corn are warm-weather crops and the areas in which successful production on a commercial scale can be accomplished are limited principally by both the general temperature conditions and the temperature at which planting may be accomplished. These limits are defined by an available thermal constant of about 1,600° (F.) for corn and about 2,000° (F.) for cotton, computed from the normal temperature when planting usually begins. It follows that if cotton could be planted with as low temperatures as corn planting is accomplished, the cotton area would be materially increased.

(5) Owing to the relatively large thermal requirements of corn and cotton, a comparatively warm spring is necessary for best results of germination and early growth. Thus there is a close relation between the spring temperatures and the condition of these crops to certain dates in the early stages of growth.

Those who have occasion to travel from one section of the United States to another and note farm activities in different localities, such as the planting and harvesting of the various crops, are impressed with the wide difference in calendar time of these operations in the northern portions of the country as compared with the southern. These differences are due, of course, to climatic conditions, particularly to the temperature, which varies greatly with the latitude, especially in the winter season. Along the immediate Gulf Coast the normal daily temperature, for example, does not go lower than 52°(F.) in winter, but in northeastern North Dakota and northern Minnesota a daily mean of zero or slightly lower, is reached in mid-winter. The 52°(F.) isothermal line which skirts the Gulf Coast about the middle of January advances northward as the season progresses, reaching western Tennessee about the middle of March, southern Iowa about the middle of April, and the north-central border of the country about the middle of May. In the meantime, the temperature along the Gulf Coast has risen to about 75°(F.), the rate of increase for the four-month period being about half as fast on this coast as in the north-central border States.

Regardless of the particular crop, or locality in which grown, there are certain definite limits of time within which planting must be accomplished for best results; and in much of the country, particularly in the central and northern districts, this period is of comparatively short duration for a given crop. These limits are defined by the temperature conditions of the locality, and while the thermal influence is obvious, the details of its control, or the measure of the significant temperature that tells us when the season for planting a particular crop has arrived, are not so generally known. Consequently, it is the object of this paper to study in some detail certain significant temperature values that seem to establish the average spring planting dates of the principal agricultural products of the country, and also the heat necessary to bring them to maturity after planting. These details of the relation of temperature to planting and harvesting dates are interesting and can often be used to considerable advantage. For example, a farmer contemplating moving from southern Georgia to, say, eastern Nebraska would doubtless know that the proper planting dates for his corn, oats, potatoes, etc., in the new location would differ greatly from those to which he had been accustomed, but he probably would not be aware of the fact that the Weather Bureau records for eastern Nebraska, properly interpreted, indicate the time at which these activities should begin, on the average, in that locality.

A certain amount of warmth is necessary for the germination of seeds, the amount required differing for seeds of different plants. Wheat and oats germinate at a much lower temperature than does corn, and corn in turn requires less warmth for successful germination than does cotton. Thus, some crops may be planted earlier in spring than others. In addition, a definite amount of heat is required after planting to bring a crop to maturity. As a rough measure of this heat there may be used what is known as the "thermal constant," which refers to the total, or accumulated day-degrees in excess of some significant temperature taken as a starting point. Investigators differ as to the temperature value from which the thermal constant should be calculated, but for spring-seeded crops it is believed that the starting point should be the mean temperature at the date of seeding.[1] The method for obtaining the thermal constant is quite simple. For example, if it is desired to compute this value for corn in a locality where the normal temperature is 55°(F.) at the average date of planting, and the mean temperature for any month during the growing season is 75°(F.), the thermal constant for that month would be $75°(F.) - 55°(F.) = 20°(F.)$, multiplied by the number of days in the month. If the normal daily temperature for any portion of a month should be less than 55°(F.), however, these days should be omitted, and only those days used which have a mean daily temperature of 56°(F.) or higher.

The thermal constant of a particular plant and the temperature at which planting may be accomplished determine whether or not the temperature conditions in a given locality are favorable for its maturity.

While the normal daily temperature at which planting usually begins differs for different plants, these measures are quite uniform for the same plant regardless of the locality, and it follows that when this significant temperature for a particular plant is known, a map may be

[1] See the effect of weather upon the yield of corn by Prof. J. Warren Smith, MONTHLY WEATHER REVIEW, 42, pp. 78-93, February, 1914.

drawn for the entire country based on this value, which will indicate approximately the average safe date for the beginning of seeding. Places in the northern United States where there are more hours of sunshine, other localities where cloudiness is slight, and still others where on account of altitude or dryness the sunlight is more intense, will usually have somewhat lower safe planting temperatures than regions where the summer days are shorter, or cloudier, or where a high moisture content of the air may keep the sunlight relatively weak. This is because soil and plant temperatures depend on sunlight as well as on air temperature. (See pp. 327–328).

The following summary indicates for the country east of the Rocky Mountains the normal daily temperatures at which planting of the more important crops usually begins in spring, and also the dates on which the temperature rises to these values in the different sections of this area. The planting and harvesting dates used for determination of the corresponding temperatures are based on numerous reports collected by the Bureau of Crop Estimates and the Office of Farm Management. (See O. E. Baker, C. F. Brooks, and R. G. Hainsworth, "A Graphic Summary of Seasonal Work on Farm Crops," Yearbook of the U. S. Department of Agriculture, 1917, pp. 537–589, 90, figs., see pages 323–327 below.)

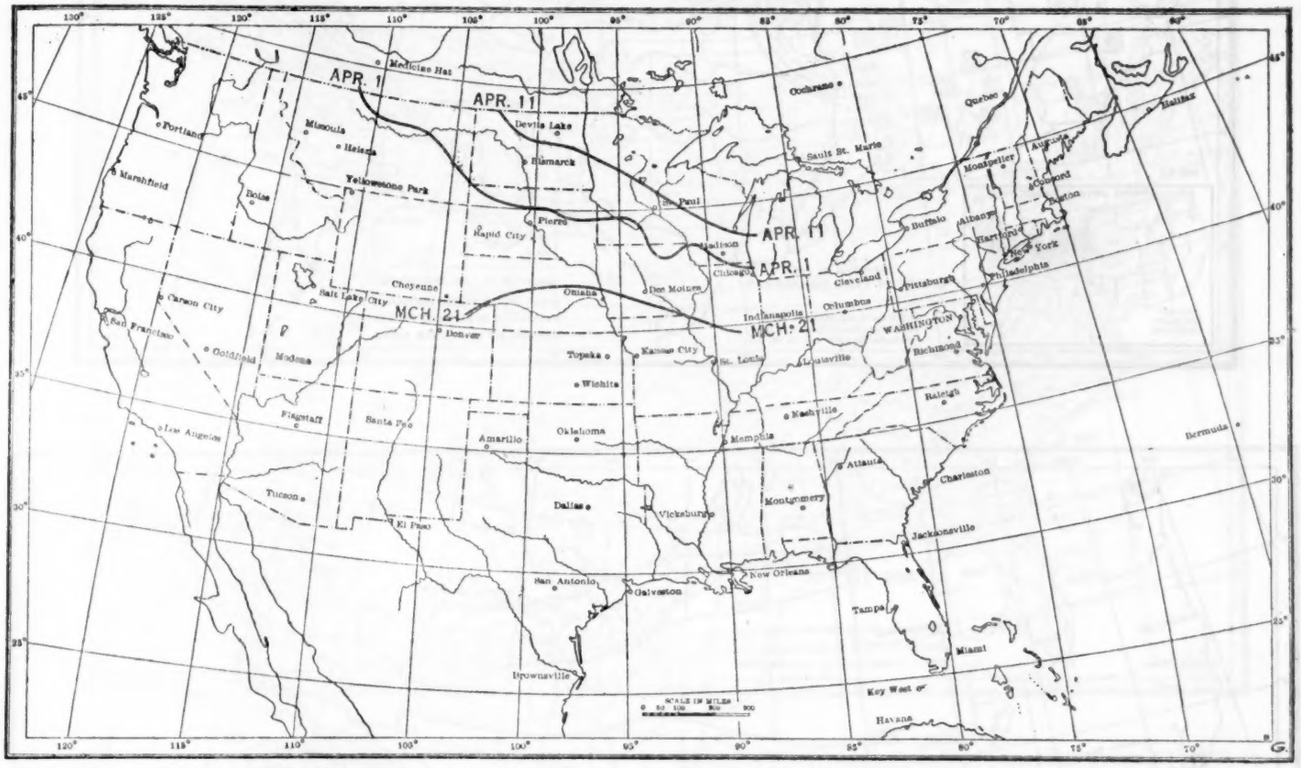

FIG. 1. Date in spring when the normal daily temperature rises to 37° in the western spring wheat belt and to 40° in the eastern (corresponding to the average date on which spring wheat seeding begins).

SPRING WHEAT.

The principal spring-wheat belt comprises the States of Minnesota and the Dakotas. From a thermal standpoint spring wheat is seeded earlier than any of the other major crops. Sowing usually begins in the Dakotas and Nebraska when the normal daily temperature rises to 37°(F.), and in Minnesota and Wisconsin when it rises to 40°(F.). Figure 1 indicates the dates on which these temperatures are reached in the different portions of the spring wheat belt. The seeding begins in the southern portion of the belt about the 20th of March and progresses northward at an average rate of about 20 miles a day, reaching northeastern North Dakota and northern Minnesota about the middle of April, the isochronal line keeping pace with the isothermal line indicated. The sowing of spring wheat becomes general about 10 days after the time of beginning.

SPRING OATS.

The successful growth of spring oats is not so geographically restricted as is that of spring wheat, there being more or less of this crop grown in nearly all sections of the United States. The principal spring-oat belt, however (see fig. 2), consists of a crescent-shaped area, extending from New England to North Dakota, bounded on the north by the Great Lakes and on the south and west by a curved line extending across central Ohio, Illinois, eastern Nebraska, and thence northwestward along the Missouri River. Spring oats is the second in order of temperature of the spring crops sown. Seeding begins north of the Gulf States when the normal daily temperature rises to 43°(F.), except in an area comprising Oklahoma, Kansas, Missouri, and the lower Ohio Valley, where it begins while the temperature is about 3°(F.) lower. Seeding begins in the central and southern Gulf States at higher temperatures than 43°(F), due to the fact that the normal daily temperature does not go as low as 43°(F.) in that area. Very little of this crop is grown, however, in these southern districts. It will be noted that spring-oat seeding begins simultaneously with

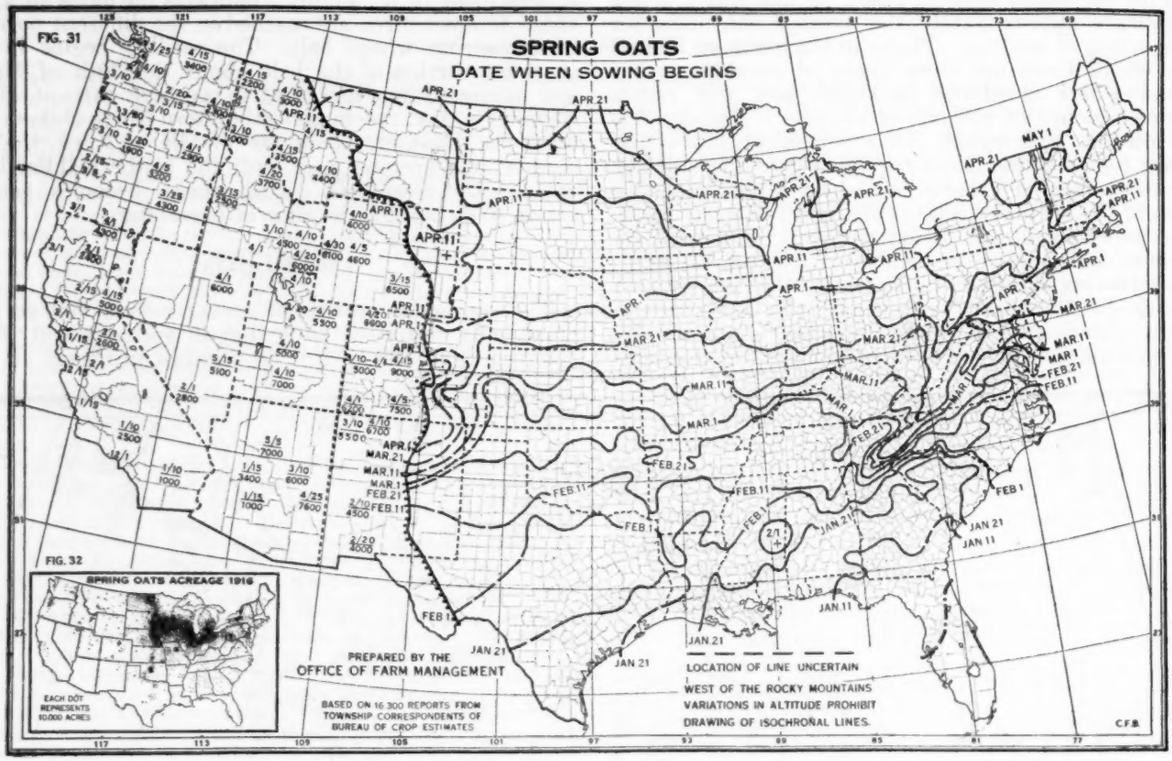
FIG. 31
SPRING OATS
DATE WHEN SOWING BEGINS
FIG. 32
SPRING OATS ACREAGE 1918
EACH DOT REPRESENTS 10,000 ACRES
PREPARED BY THE OFFICE OF FARM MANAGEMENT
BASED ON 16,300 REPORTS FROM TOWNSHIP CORRESPONDENTS OF BUREAU OF CROP ESTIMATES
LOCATION OF LINE UNCERTAIN WEST OF THE ROCKY MOUNTAINS VARIATIONS IN ALTITUDE PROHIBIT DRAWING OF ISOCHRONAL LINES.
C.F.B.

FIG. 2.

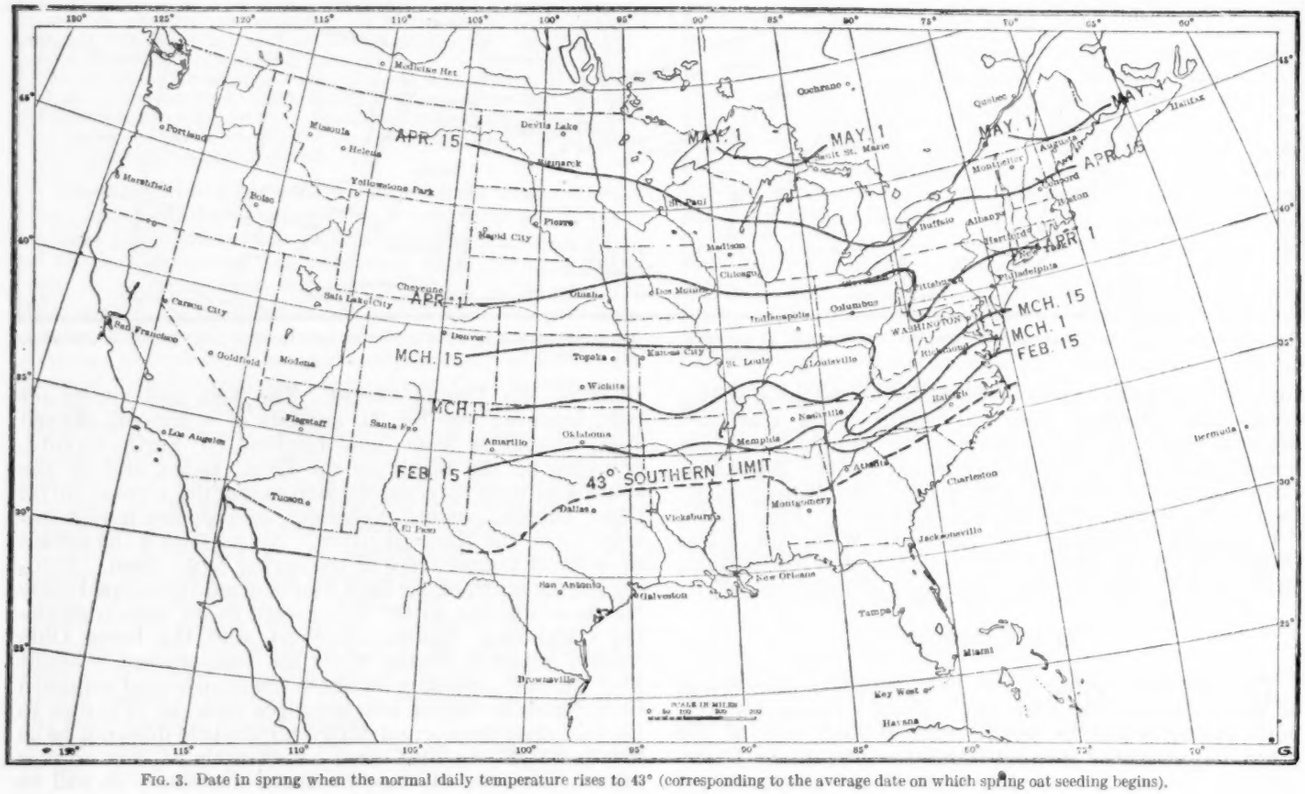

FIG. 3. Date in spring when the normal daily temperature rises to 43° (corresponding to the average date on which spring oat seeding begins).

the advent of the vegetative period in spring; this also corresponds to the time when the normal daily minimum temperature passes above the frost line (32°(F.)).

Figure 3 shows the northward progression of the mean daily isotherm corresponding to the average dates on which oat seeding begins. It will be noted that it requires a period of two months for this work to move northward from central Oklahoma to southeastern North Dakota, an average rate of about 13 miles a day, although the progress is much faster from central Nebraska northward, due to the rapid increase in temperature as spring advances. The dotted line on figure 4 shows the southern limit of the area in which the mean daily temperature falls below 43° (F.) in winter.

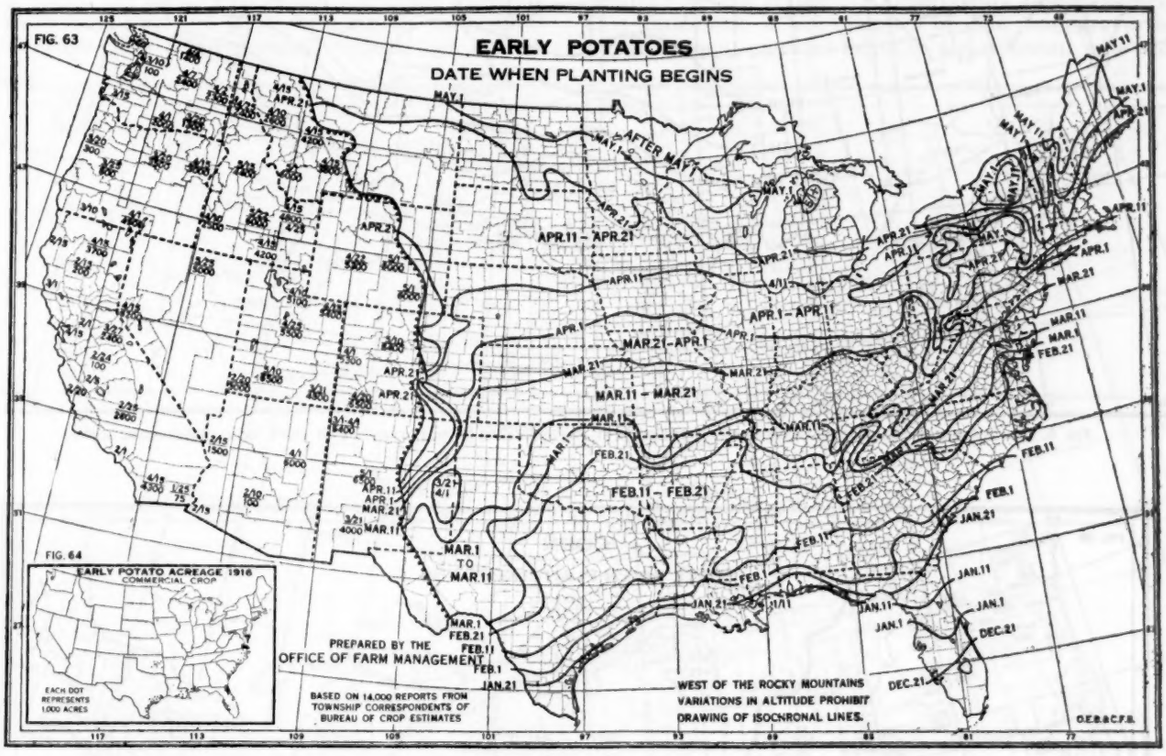
FIG. 63
EARLY POTATOES
DATE WHEN PLANTING BEGINS
AFTER MAY 1
APR.11 - APR.21
APR.1 - APR.11
MAR.21 - APR.1
MAR.11 - MAR.21
FEB.11 - FEB.21
MAR.1 TO MAR.11
FIG. 64
EARLY POTATO ACREAGE 1916
COMMERCIAL CROP
EACH DOT REPRESENTS 1,000 ACRES
PREPARED BY THE OFFICE OF FARM MANAGEMENT
BASED ON 14,000 REPORTS FROM TOWNSHIP CORRESPONDENTS OF BUREAU OF CROP ESTIMATES
WEST OF THE ROCKY MOUNTAINS VARIATIONS IN ALTITUDE PROHIBIT DRAWING OF ISOCHRONAL LINES.
O.E.B.&C.F.B.

FIG. 4.

EARLY POTATOES.

The normal daily temperature at which early potato planting begins follows soon after that for the sowing of spring oats (see fig. 4). This operation begins, on the average, when the temperature rises to 45°(F.), except in the Gulf coast section where mean daily temperatures as low as this are not reached during the winter. Figure 5 shows the northward progression of the 45°(F.)-isotherm, which corresponds almost exactly to the general progress of the isochronal line of the beginning of early potato planting north of the 45°-limit shown on the chart. In the more southern districts planting dates range from the latter part of December in central Florida to about February 10 in the central Gulf States. The temperatures in these southern localities range from 50° (F.) in the northern portion to 60°(F.) in central Florida, as shown on figure 5. The 45°(F.) isotherm crosses the northern portion of the Gulf States about February 15 and moves thence northward simultaneously with the isochronal line of the beginning of early potato planting, to the northern border States by May 1. Thus the planting of early potatoes usually begins in northern Mississippi about February 15 and in northern Wisconsin two and one-half months later, but in each locality when the normal daily temperature rises to 45°(F.).

CORN.

Owing to the greater thermal requirements of corn for germination and growth this crop can not be planted until the soil becomes much warmer than is necessary for spring wheat, oats, or potatoes (see fig. 6 and compare with figs. 2 and 4). The temperature at which corn planting usually begins varies slightly for different sections of the country, but is generally from 54°(F.) to 57° (F.), or about 10° higher than for early potatoes and 15°(F.) higher than for spring wheat. Figure 7 shows the normal daily temperature for different sections of the country east of the Rocky Mountains at which corn planting begins on the average and also the dates on which this temperature is reached in the several localities. It will be noted that in a small area of the southern Great Plains corn planting begins while the normal daily temperature is from 3°(F.) to 5°(F.) lower than in other sections of the country, which causes a slight northward bend in the isochronal lines in that area. However, when it is considered that planting begins in the extreme South about 3 months earlier than in the northern border States, the uniformity in the planting temperatures for the various sections is noteworthy. It should also be noted that a mean daily temperature of 55°(F.) in spring corresponds to the average date of the last killing frost.[1]

[1] *Cf.* J. B. Kincer, Relation between Vegetative and Frostless Periods, MONTHLY WEATHER REVIEW, 1919, 47: 106–110.

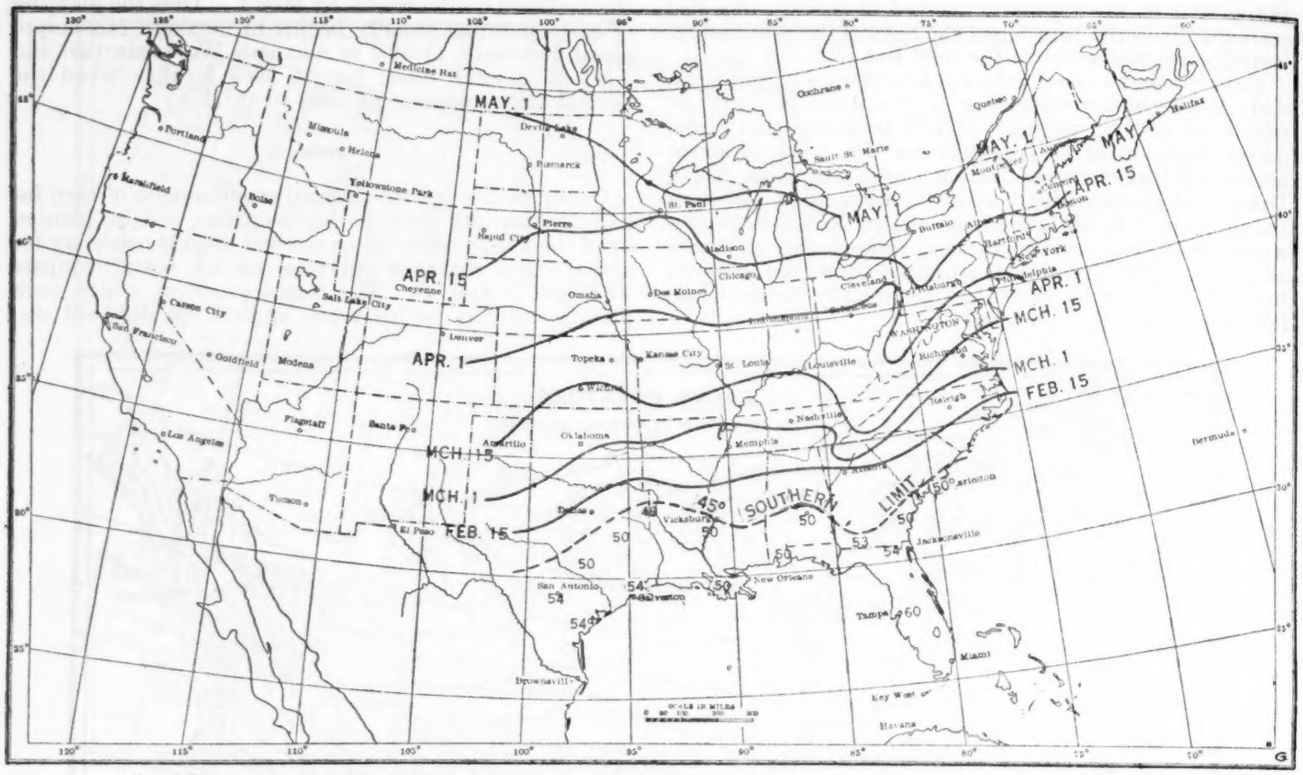

FIG. 5. Date in spring when the normal daily temperature rises to 45° (corresponding to the average date on which early potato seeding begins).

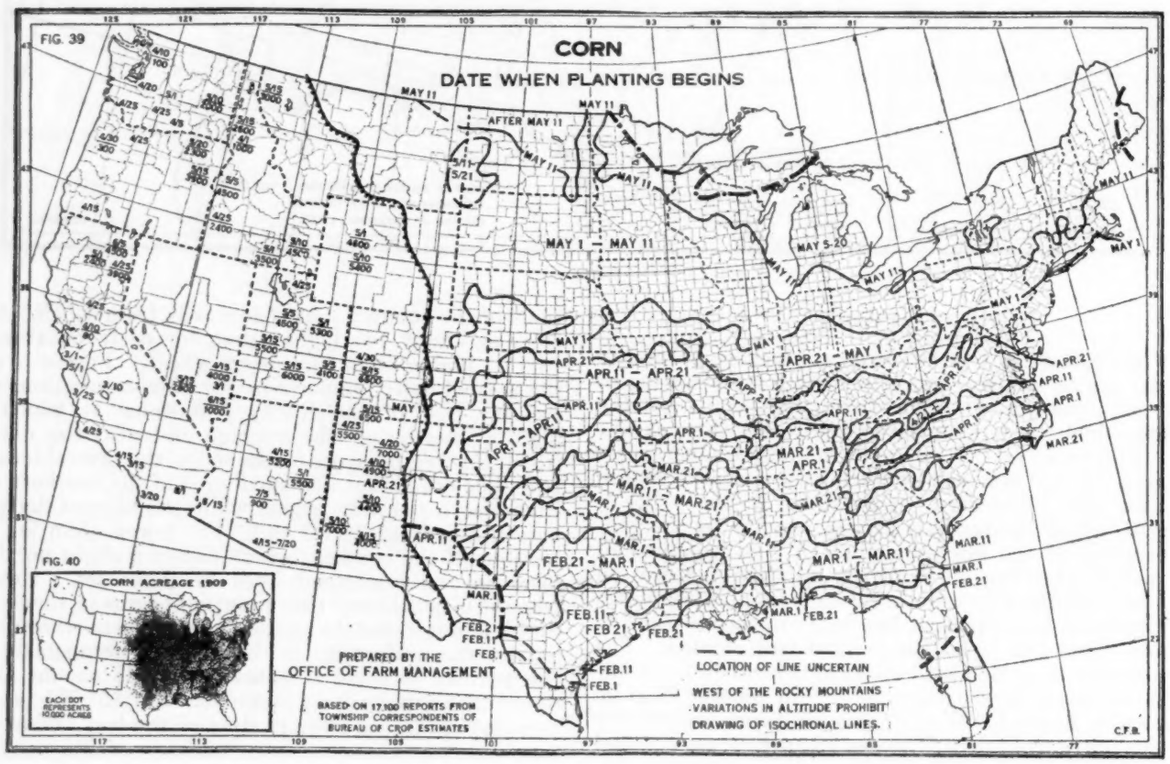

FIG. 6.

Therefore a map showing the average dates of the last killing frost in spring indicates also, approximately, the average dates of the beginning of corn planting.

COTTON.

Cotton requires for satisfactory germination and early growth more warmth than is required for any of the other staple crops grown in the United States. Cotton seed can not be planted until the soil is thoroughly warm, and consequently planting usually does not begin in the eastern portion of the belt until the normal daily temperature rises to 60°(F.) or 62°(F.), and not in the western portion until 61°(F.) to 63°(F.) is reached. Figure 9 shows the dates on which the temperature rises to these values in the different sections of the cotton belt, which corresponds to the average time when planting begins (see fig. 8).

Figures 10 to 13 show graphically the time of the beginning of planting and of harvest of the crops discussed above in their temperature and geographic relation. They represent a belt extending across the country from northern North Dakota southeastward to southern Georgia. Graph No. 1 (fig. 10) represents the area in North Dakota between Bismarck and Devils Lake; No. 2 (fig. 11), east central Nebraska; No. 3 (fig. 12), extreme western Tennessee; and No. 4 (fig. 13), southern Georgia between Macon and Thomasville.

The ends of the heavy arcs within the circles of each graph show, respectively, the time of the beginning of planting and of harvest of the several crops named. The figures within the circle show the annual march of temperature for the respective localities by 10-day intervals. This facilitates a comparison of the temperatures at which these operations begin in the different and widely

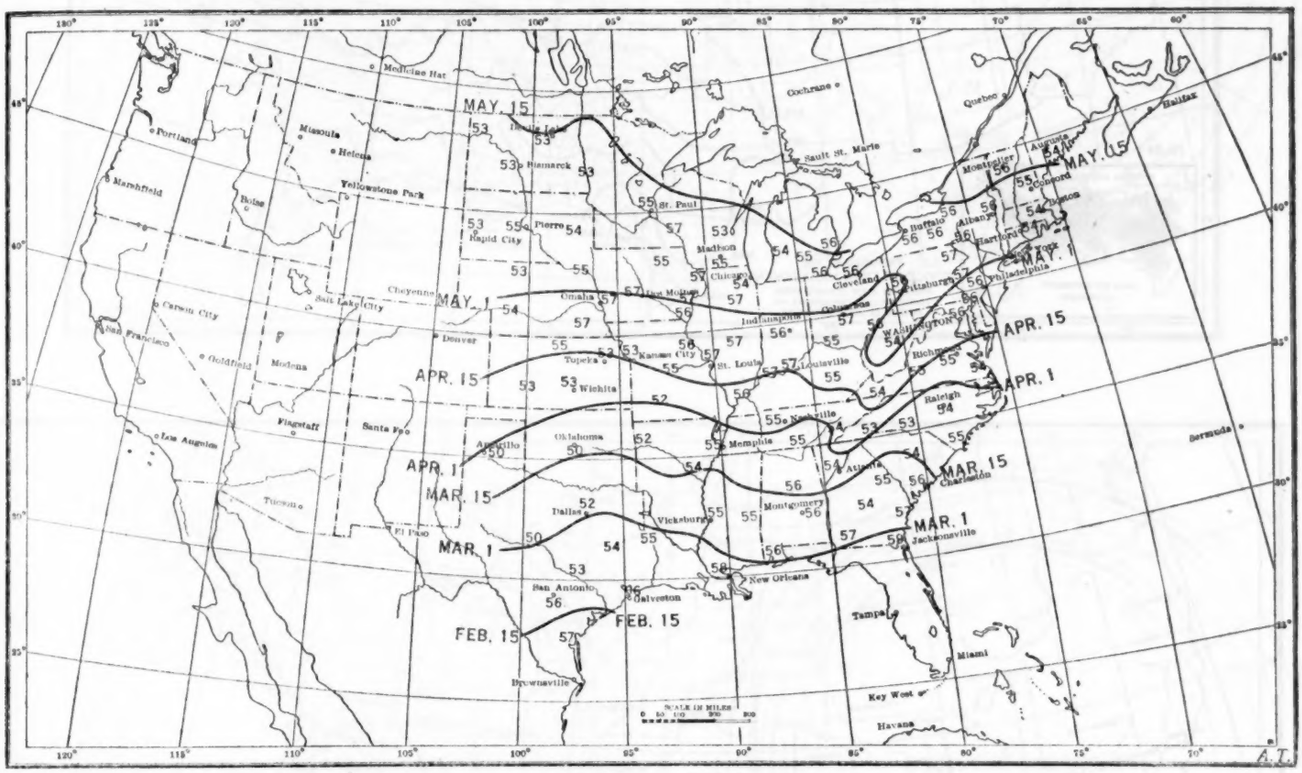

FIG. 7. Normal daily temperature at the average date of beginning of corn planting and the date on which this temperature is reached.

These dates vary from the first of March in extreme southern Texas to the last decade in April in the northern portion of the belt.

It is interesting to note the two extreme temperature requirements for planting the staple crops grown in the United States, spring wheat and cotton, the former coming into best development only in the northern portions of the country, and the latter only in the southern. We find that spring wheat may be planted when the normal daily temperature rises to 37°(F.), and that cotton as a rule will not germinate satisfactorily if planted before the daily temperature rises to 60°(F.). The fact that this country affords opportunity for the growing on a large commercial scale of these two important crops, requiring such a large difference in temperature conditions for successful development, emphasizes its geographic magnitude and diversity of climate.

separated localities. These graphs bring out in an interesting way the short space of time within which the staple spring crops must be planted in northern districts as compared with the southern section of the country. In northern North Dakota, for example, the planting of the four crops shown in figure 10 should begin within a period extending but slightly over one month, while in southern Georgia the beginning of planting of the several crops may extend over a period of about two and one-half months. It will be noted also that for a particular crop grown in each locality planting is begun at practically the same temperature. The harvesting of corn is shown as the time when cutting and shocking begin, which, however, is not the general method of harvest in all localities, but is the common practice in the dairy States of the North, also in Ohio, West Virginia, Maryland, Virginia, and portions of Kentucky and Missouri.

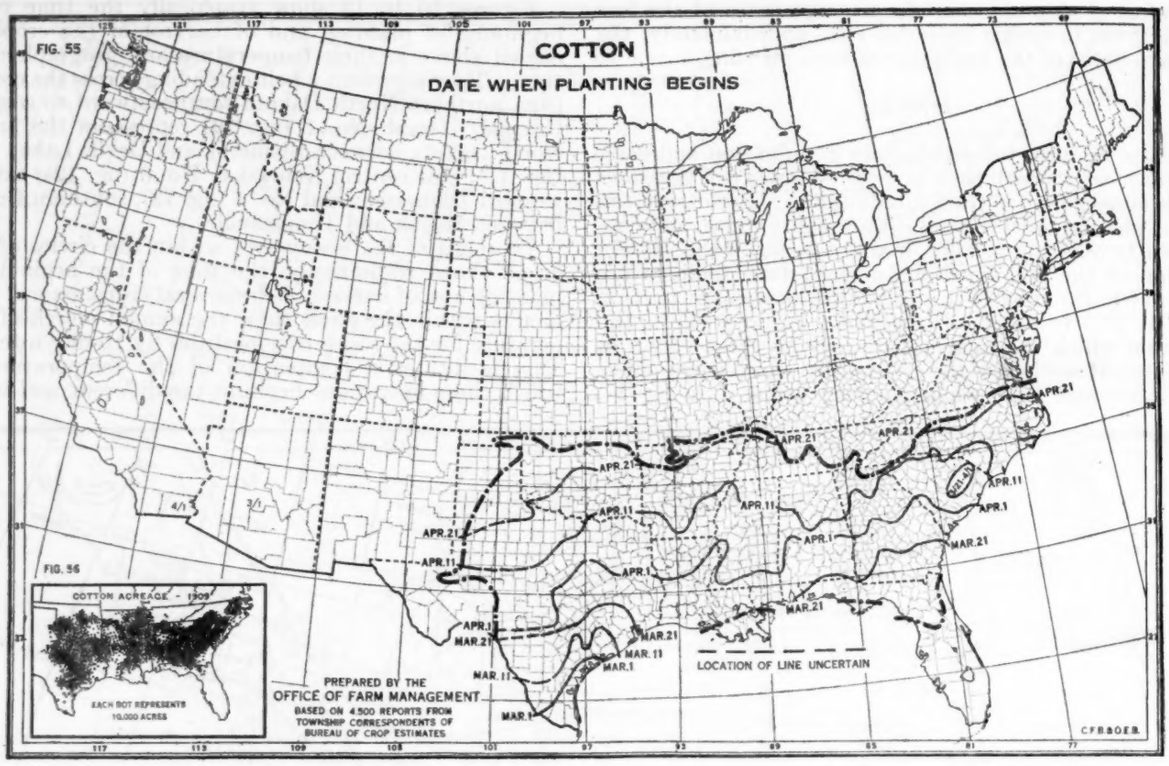

FIG. 8.

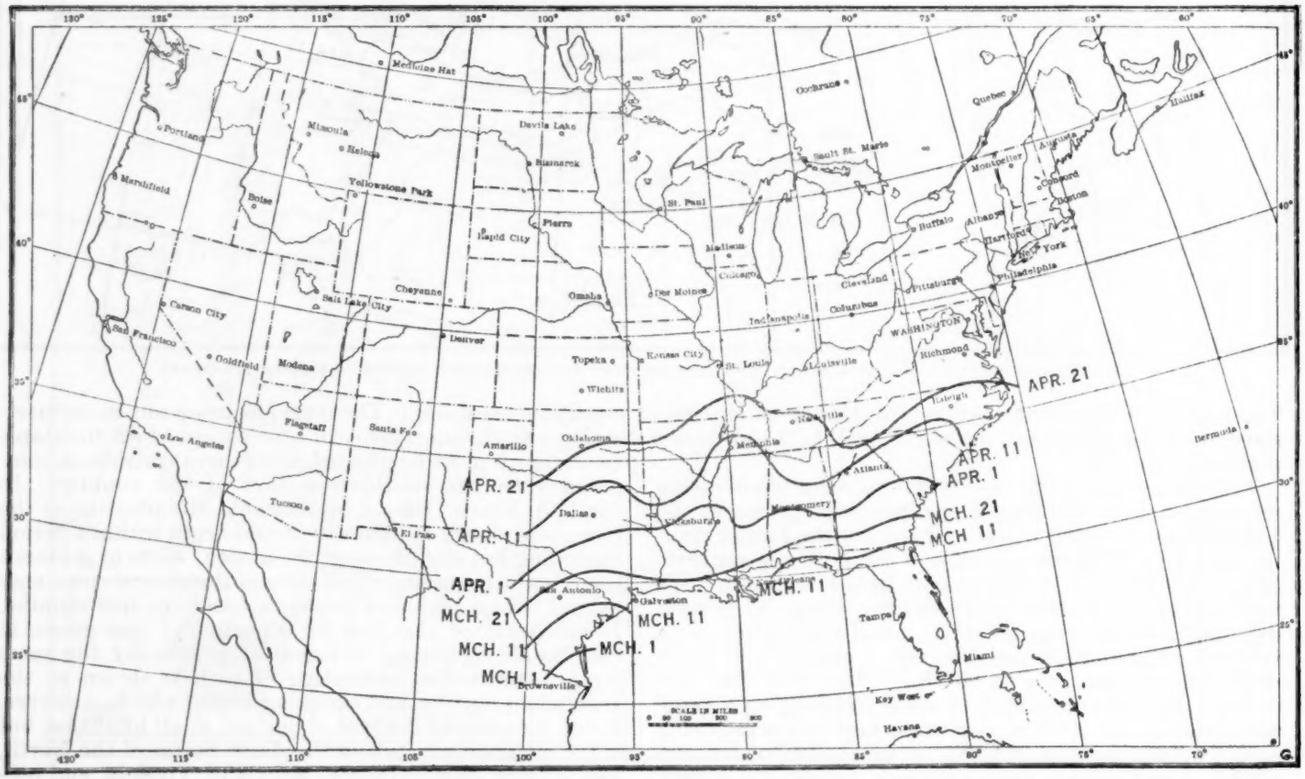

FIG. 9. Date in cotton belt on which the normal daily temperature rises to 63° west of the Mississippi River and to 60° east (corresponding to the average date on which cotton planting begins).

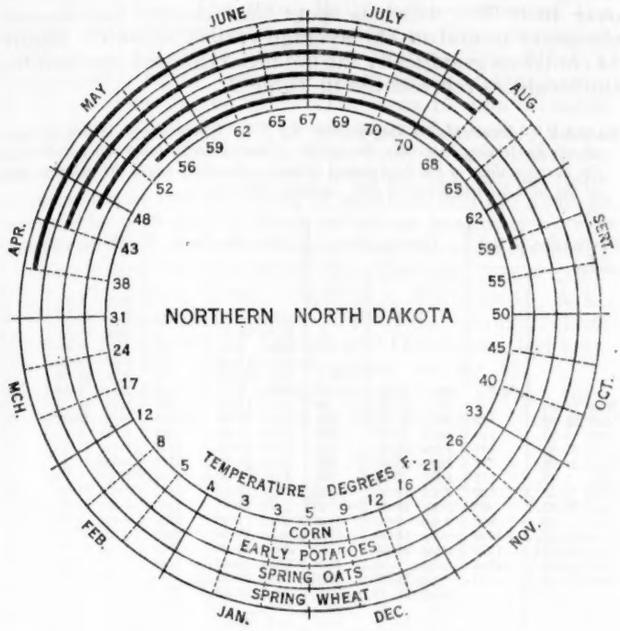

FIG. 10.

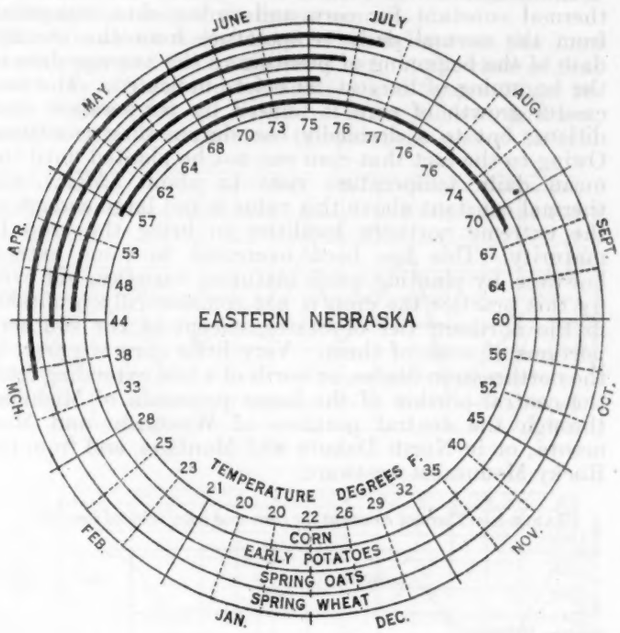

FIG. 11.

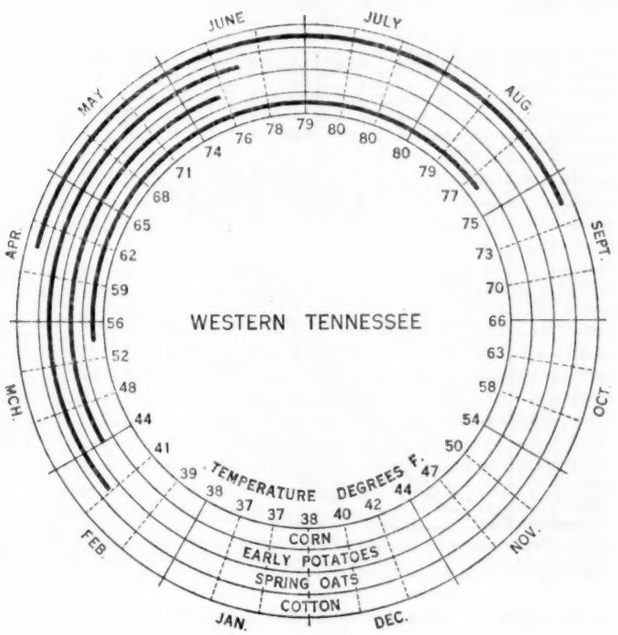

FIG. 12.

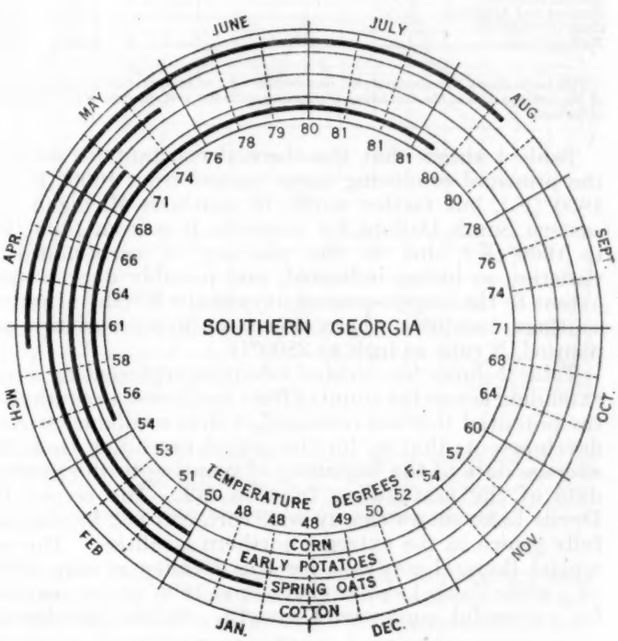

FIG. 13.

FIGS. 10-13. Annual march of temperature by 10-day intervals and the time of beginning of planting and of harvest of certain crops.

THERMAL CONSTANT.[1]

Table 1 shows for various sections of the country the thermal constant for corn and spring oats, computed from the normal daily temperature from the average date of the beginning of planting to the average date of the beginning of harvest, as before indicated. The successful growth of corn is limited by temperature conditions, but to a decidedly less degree than is cotton. Owing to the fact that corn can not be planted until the mean daily temperature rises to about 55°(F.), the thermal constant above this value is not large enough in the extreme northern localities to bring the crop to maturity. This has been overcome to some extent, however, by planting quick maturing varieties, but even by this practice the crop is not commercially profitable in the northern tier of States, except in the southern portions of some of them. Very little corn is grown in the northeastern States, or north of a line extending from the central portion of the lower peninsula of Michigan through the central portions of Wisconsin and Minnesota; or in North Dakota and Montana, and from the Rocky Mountains westward.

TABLE 1.—*Thermal constant for corn and oats, selected localities.*

Localities.	Corn.	Spring oats.
Southern Michigan	1,416	1,887
Eastern South Dakota	1,592	2,018
Eastern Nebraska	1,811	2,016
Central Iowa	1,630	2,006
Central Illinois	1,932	2,164
Central Ohio	1,757	2,198
Southeastern Pennsylvania	1,995	2,204
East-central North Carolina	2,563	1,962
Eastern Tennessee	2,493	2,067
Central South Carolina	2,813	1,881
Central Alabama	2,700	1,845
Central Missouri	2,300	1,960
East-central Arkansas	2,864	2,069
Central Oklahoma	2,729	2,195
Eastern Texas	2,543	1,854

This table shows the accumulated day-degrees (F.) of temperature in excess of that at the average date of the beginning of planting until the average date of the beginning of harvest.

Table 1 shows that the thermal constant for corn in the principal producing areas ranges from 1600°(F.) to 1800°(F.), but farther north, in southern Michigan and eastern South Dakota for example, it is from 1400°(F.) to 1600°(F.), due to the planting of early-maturing varieties, as before indicated, and possibly due to some extent to the longer summer days in the North. In some southern localities where slower-maturing varieties are planted, it runs as high as 2800°(F.).

Table 2 shows for selected localities, representing a belt extending across the country from northwest to southeast, the potential thermal constant, or that available for corn development; that is, for the period extending from the average date of the beginning of planting to the average date of the first killing frost in fall. The record for Devils Lake shows clearly why corn can not be successfully grown in the extreme northern localities. The potential thermal constant for this locality is only 1260° (F.) while Table 1 shows that about 1600°(F.) is required for successful commercial growth. While the thermal constant is thus deficient in the North, it is interesting to note the large surplus available in the South; in southern Georgia, for example, the potential thermal constant is over 4000°(F.), which is more than double the amount necessary to mature the average variety of corn. Figure 14 contrasts graphically the potential thermal constant for the localities represented in Table 2.

TABLE 2.—*Accumulated day-degrees (F.) of temperature (thermal constant) by 10-day intervals, in excess of the normal daily temperature at the average date of the beginning of corn planting until the average date of the first killing frost in fall, selected stations.*

Devils Lake, N. Dak.		Lincoln, Nebr.		Memphis, Tenn.		Thomasville, Ga.	
							°(F.)
						Mch. 1-10.	13
					°(F.)	Mch. 11-20.	44
				Mch. 23-31.	9	Mch. 21-31.	100
				Apr. 1-10.	48	Apr. 1-10.	173
				Apr. 11-20.	115	Apr. 11-20.	270
	°(F.)		°(F.)	Apr. 21-30.	214	Apr. 21-30.	391
May 15-20.	3	May 1-10.	25	May 1-10.	344	May 1-10.	537
May 21-31.	42	May 11-20.	83	May 11-20.	501	May 11-20.	708
June 1-10.	110	May 21-31.	184	May 21-31.	701	May 21-31.	915
June 11-20.	209	June 1-10.	307	June 1-10.	909	June 1-10.	1127
June 21-30.	331	June 11-20.	455	June 11-20.	1137	June 11-20.	1353
July 1-10.	474	June 21-30.	623	June 21-30.	1383	June 21-30.	1590
July 11-20.	629	July 1-10.	808	July 1-10.	1634	July 1-10.	1835
July 21-31.	800	July 11-20.	1005	July 11-20.	1894	July 11-20.	2085
Aug. 1-10.	945	July 21-31.	1225	July 21-31.	2180	July 21-31.	2360
Aug. 11-20.	1069	Aug. 1-10.	1418	Aug. 1-10.	2434	Aug. 1-10.	2610
Aug. 21-31.	1176	Aug. 11-20.	1594	Aug. 11-20.	2679	Aug. 11-20.	2850
Sept. 1-10.	1241	Aug. 21-31.	1760	Aug. 21-31.	2929	Aug. 21-31.	3104
Sept. 11-15.	1260	Sept. 1-10.	1878	Sept. 1-10.	3134	Sept. 1-10.	3321
		Sept. 11-20.	1962	Sept. 11-20.	3314	Sept. 11-20.	3521
		Sept. 21-30.	2007	Sept. 21-30.	3463	Sept. 21-30.	3697
		Oct. 1-10.	2017	Oct. 1-10.	3579	Oct. 1-10.	3845
		Oct. 11-13.	2017	Oct. 11-20.	3656	Oct. 11-20.	3960
				Oct. 21-31.	3694	Oct. 21-31.	4045
				Nov. 1- 2.	3696	Nov. 1-10.	4087
						Nov. 11-14.	4096

It is also interesting to note that the large difference in the thermal constant for corn between the northern and the southern localities, as shown in Table 1, does not exist in the case of oats. The reason for this is that this crop is planted at temperatures about 12°(F.) lower than corn, and consequently the thermal constant is ample for maturity, making it unnecessary to develop special varieties, as in the case of corn.

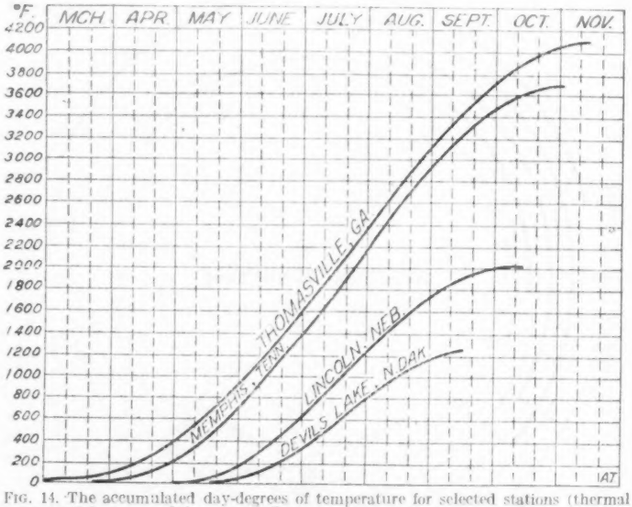

FIG. 14.—The accumulated day-degrees of temperature for selected stations (thermal constant) in excess of the mean daily temperature at the beginning of corn planting until the average date of the first killing frost in fall (see Table 2).

The thermal constant for cotton computed from the mean daily temperature at the average date of the beginning of planting to the average date of the beginning of harvest in selected localities in the cotton belt is as fol-

[1] Cf. C. Hart Merriam, "Laws of temperature control of the geographic distribution of animals and plants." Nat'l Geogr. Mag., 1894, 6:229-238, 3 colored maps. (One of these maps, life zones, is reproduced as pl. I of vol. 37, Bull. Torrey Botanical Club.) A note by Dr. Merriam, Science, 1899, N. S., vol. 9, p. 116, says that, by mistake, the temperature summations published in the original table did not have 6° C. deducted when they were made. See also, C. H. Merriam, "Life zones and crop zones of the United States," Bull. 10, U. S. Biol. Surv., Part 3 is, "Laws of temperature control of the geographic distribution of plants and animals."

Dr. Merriam seems to have originated this temperature summation method from 6°C. as zero, for a close study of the biological effect of seasonal temperatures.—C. F. B.

lows: Raleigh, N. C., 1860°(F.); Thomasville, Ga., 1975° (F.); Montgomery, Ala., 1900°(F.); Little Rock, Ark., 1910°(F.); Oklahoma, Okla., 1820°(F.); and Galveston, Tex., 1810°(F.). The mean daily temperature at the average date of beginning of planting in these respective localities is: Raleigh, 60°(F.); Thomasville, 61°(F.); Montgomery, 62°(F.); Little Rock, 62°(F.); Oklahoma, 61°(F.); Galveston, 63°(F.). The area in which cotton can be successfully grown in commercial quantity has a well defined thermal limit. This limit is established by about 2000° thermal constant between the normal daily temperature at the beginning of planting and the average date of the first killing frost in fall as is shown by the records for the following localities near the northern limits of the belt: Norfolk, Va., 2010° (F.); Raleigh, N. C., 2190° (F.); Chattanooga, Tenn., 2000°(F.); Fort Smith, Ark., 2040°(F.); Oklahoma, Okla., 2140°(F.). Some cotton is grown a little north of Raleigh and Oklahoma, but very little north of the other points named (see fig. 8).

By comparing the thermal constant for cotton thus computed with that for corn in the principal corn belt

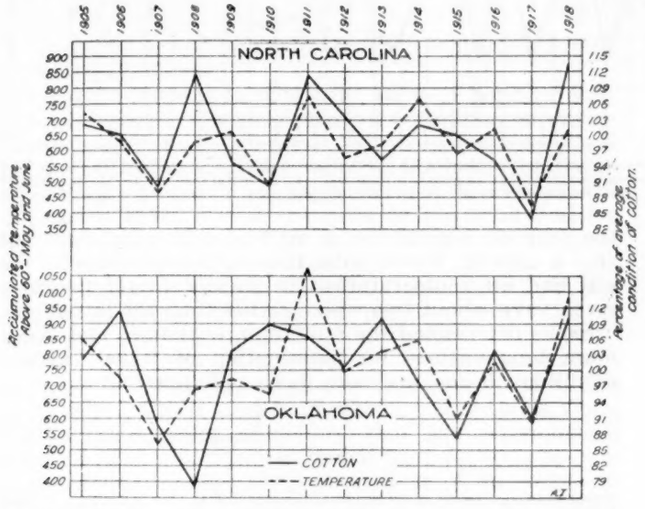

FIG. 15. Accumulated temperature above 60° (the normal mean daily temperature corresponding to the average date of beginning of cotton planting) for the months of May and June, and the condition of cotton on June 25 expressed in percentage of the average condition for the 14-year period, 1905–1918, as reported by the Bureau of Crop Estimates.

and, generally, for oats, as shown in Table 1 it will be seen that there is very little difference in the amount of heat necessary, when measured by accumulated temperature above the temperature at date of planting, to bring these different crops to maturity, notwithstanding oats is classed as a cool-weather crop. In the case of cotton, however, the plants continue to develop new fruit long after that first formed reaches maturity, thus requiring a longer growing season for production on a commercial scale. For successful germination and satisfactory growth in its early stages of development cotton requires also a comparatively warm spring, particularly in the northern portions of the belt where temperatures are normally lower than farther south. Figure 15 shows for North Carolina and Oklahoma for the months of May and June, and for each year from 1905 to 1918, inclusive, the accumulated temperature above 60°(F.) (the temperature at which cotton planting usually begins), and also the condition of cotton on June 25, expressed in percentages of the 14-year average condition, as reported by the Bureau of Crop Estimates. The solid lines show the condition of cotton and the broken lines the accumulated temperature. It will be seen from these graphs that, in general, there is a close relation between the temperature conditions during May and June and the condition of cotton at the close of the latter month.

There is also a well-defined relation between the June temperature and the condition of corn at the close of that month, as is indicated by Table 3 and figures 16 to 19. Table 3 shows for the States of Iowa, Illinois, Indiana, and Ohio the accumulated temperature above 55°(F.)

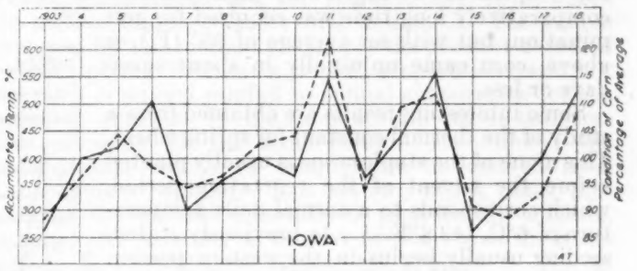

FIG. 16.

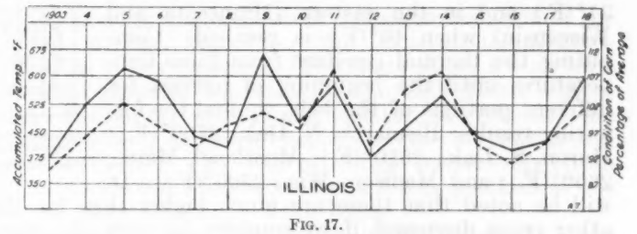

FIG. 17.

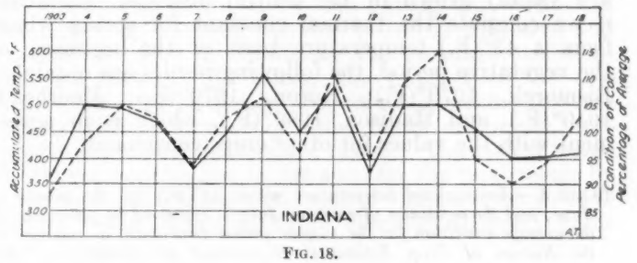

FIG. 18.

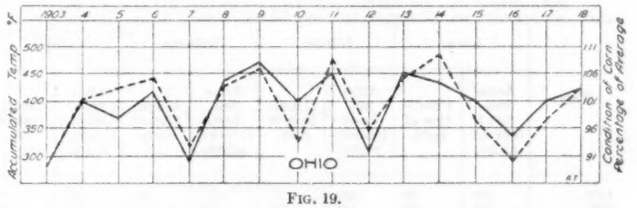

FIG. 19.

FIGS. 16 to 19, inclusive, show, for the States of Iowa, Illinois, Indiana, and Ohio, the accumulated temperature above 55° (the normal daily temperature at the average date of beginning of corn planting) for the month of June, and also the condition of corn on July 1, expressed in percentage of the average condition for the 16-year period 1903–1918, as reported by the Bureau of Crop Estimates (see Table 3). [— corn; .. temperature.]

(the normal mean daily temperature at the average date of the beginning of corn planting) for the month of June, and also the condition of corn on July 1, expressed in percentage of the average condition for the 16-year period 1903–1918, as reported by the Bureau of Crop Estimates. It will be seen from these graphs that in most cases there is a very close relation between the June temperature and the condition of corn on July 1, as thus reported.

It is also of interest to note the effect of temperature on the germination of corn, as indicated by figure 20. The

solid line in this graph shows the number of days required for corn to come up at Wauseon, Ohio, for the period from 1883 to 1912, while the dash line shows the average daily temperature in excess of 55° (F.) during the period required, after planting, for it to appear above ground in each year. The records on which this graph is based were made by Mr. Thomas Mikesell, of Wauseon, Ohio; they appear in Supplement No. 2, MONTHLY WEATHER REVIEW, September, 1915. It will be noted that when the temperature averaged only slightly above 55°(F.), a comparatively long time was required for germination, but with an average of 65° (F.), or above, corn came up usually in about seven days or less.

Some interesting results are obtained from a study of the thermal constant for spring wheat. This alone of the staple crops is usually planted before the advent of the vegetative period, which corresponds to a normal daily temperature of 6°C. (42.8°F.).[1] As previously stated, seeding usually begins in the western portion (Dakotas and Nebraska) of the spring-wheat belt when the mean daily temperature rises to 37°(F.) and in the eastern (Minnesota and Wisconsin) when 40°(F.) is reached. Computing the thermal constant from these temperatures until the beginning of harvest for different portions of the belt, we find the following results: Bismarck, N. Dak., 2700°(F.); Huron, S. Dak., 2680°(F.); Moorhead, Minn., 2660°(F.); and Madison, Wis., 2300°(F.). It will be noted that these are much higher than for the other crops discussed, if we consider for corn the average variety grown in the central districts. However, if we compute the thermal constant for spring wheat from a 43°(F.) temperature base, or the beginning of the vegetative period, the following results are obtained: Bismarck, 1970°(F.); Huron, 1970°(F.); Moorhead, 1940°(F.); and Madison, 1980°(F.), which is in agreement with the values for other crops considered.

TABLE 3.—*Accumulated temperature above 55°(F.) for the month of June, and the condition of corn on July 1, expressed in percentage of the average condition for the 16-year period 1903–1918, as reported by the Bureau of Crop Estimates, Department of Agriculture. (See figures 16 to 19.)*

Year.	Iowa.		Illinois.		Indiana.		Ohio.	
	Accumulated temperature.	Condition of corn.	Accumulated temperature.	Condition of corn.	Accumulated temperature.	Condition of corn.	Accumulated temperature.	Condition of corn.
1903	288	86	339	92	333	91	282	89
1904	363	100	441	102	438	105	402	101
1905	447	102	528	109	501	104	426	98
1906	387	111	465	106	477	102	444	103
1907	345	90	402	96	387	93	318	90
1908	363	96	465	94	474	99	426	104
1909	423	100	507	111	516	111	453	108
1910	435	97	453	99	408	100	327	101
1911	621	114	615	105	555	108	477	106
1912	336	96	492	92	399	92	348	92
1913	495	103	567	98	546	105	444	106
1914	516	116	615	104	600	105	483	104
1915	303	86	495	96	402	101	354	101
1916	285	93	366	94	348	95	291	94
1917	330	100	405	95	393	95	357	101
1918	474	112	513	107	474	96	414	103

The question of the difference in air temperature and the temperature of the soil near the surface where germination is effected is one of considerable importance in studying the relation of air temperature to planting dates as outlined on the basis of the Wauseon records. Observations of soil temperature at Lincoln, Nebr., made during the period from 1888 to 1902, published in the sixteenth annual report of the Nebraska Agricultural Experiment Station, January, 1903, pages 95–102, show that the soil temperature during the spring months at 2 or 3 inches below the surface at that point is usually 5 or 6 degrees higher than that of the air. At this season of the year the normal rise in air temperature is about 10° (F.) a month; hence, with this difference between the soil and air temperatures, the former would rise to a given value about two weeks earlier than the latter.

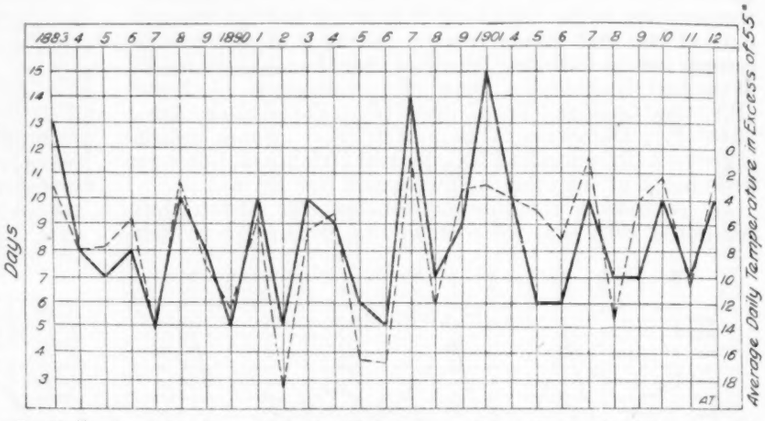

FIG. 20. Number of days from corn planting till plants appeared above the ground and the average daily excess of temperature above 55° for those days in each year. From records made by Mr. Thomas Mikesell at Wauseon, Ohio (records were incomplete for 1900, 1902, and 1903). [—days; .... temperature.]

Sachs determined the minimum, optimum, and maximum temperatures for germination of wheat, barley, pumpkins, beans, and corn to be as follows:[1]

Plant.	Minimum.	Optimum.	Maximum.
	° F.	° F.	° F.
Wheat	41	83.7	108.5
Barley	41	83.7	99.9
Pumpkin	56.7	92.7	115.2
Beans	49.1	92.7	115.2
Corn	49.1	92.7	115.2

It appears from the above, and the conclusions of other investigators, that the optimum temperature for a considerable number of plants is between 83° and 95°(F.). In considering the minimum temperature of germination in its relation to safe or usual planting dates from year to year, however, the short period fluctuations, or temperature variability, plays an important part. The characteristic alternations of cool and warm periods serve in the long run to advance the date of the normal daily temperature at which germination will take place to a season earlier than planting can safely be accomplished. If corn, for example, should be planted in spring as soon as the soil temperature rises to 49° or 50°(F.), or even the normal air temperature rises to that value, there would often follow a period too cool for germination, resulting in the decay of seeds.

Some experiments have been made by H. N. Vinall and H. R. Reed, of the Bureau of Plant Industry, to determine the effect of weather on the growth of sorghums

[1] Ibid., cf. also J. B. Kincer, loc. cit.

[1] From Vinall, H. N., and Reed, H. R., "Effect of temperature and other meteorological factors on the growth of sorghums," Jour. Agr. Research, 1918, 13: 133-147.

under widely varying climatic conditions.[1] Observations were made at Puyallup, Wash.; Chico, Berkeley, Bard, Chula Vista, and Pasadena, Cal.; and Chillicothe, Tex. The authors summarize as follows:

(1) Sorghum is semitropical in its adaptations and does not thrive in regions of low temperatures.

(2) Sunshine is probably an important factor of growth, as evidenced by the difference of growth at Chula Vista, Calif., and Puyallup, Wash., where the mean temperatures and the total positive heat units available are but little different.

(3) The "physiological constant" for the ripening phase of sorghums according to Linsser's law of growth is about 0.53.

(4) Extremely high temperatures during the period of flowering and fruiting result in a decreased yield of seed.

(5) The date of planting should be so arranged that germination and early growth of the plants will take place during the period of high temperatures, and the flowering and fruiting when more moderate temperatures prevail.

(6) Adverse weather conditions affect such supposedly stable characters as the number of leaves per plant, as well as the volume of growth.

Linsser's law and its application to the matter in hand are given as follows:

"In two different localities the sums of positive daily temperatures for the same phase of vegetation is proportional to the annual sum total of all positive temperatures for the respective localities—that is, the heat required in any locality to produce a given phase of development in vegetation bears a constant ratio to the total positive heat units available in that place. This ratio has been styled the "physiological constant." If 50° (F.) is considered as the minimum temperature for growth in the sorghums, the yearly total of positive heat units at Chillicothe in 1915 was 5618° (F.); at Bard, 1915, 7989°; and at Chula Vista, 1916, 3600°. The positive heat unit required to bring the sorghums to maturity at Chillicothe were 3028° (F.), at Bard, 4236°, and at Chula Vista, 1,895°. It appears, therefore, that the physiological constant of sorghum for the period from planting to maturity is about 0.53. The conformance of the sorghums in these three cases to Linsser's law is rather remarkable, the exact ratio in each case being as follows:

Chillicothe	3,028;	5,618;	or 0.539
Bard	4,236;	7,989;	or 0.530
Chula Vista	1,895;	3,600;	or 0.526

[1] Ibid.

"Although Linsser's law seems to furnish a rule for the behavior of sorghums in respect to temperature, it does not take into account the effect of sunlight and other factors, which are also important."

Prof. Livingston has proposed a method by which both the moisture and temperature factors as affecting the growth of plants may be expressed as a single numerical value. The index thus proposed is the product of three factors—rainfall, evaporation, and temperature. (See Physiological Researches, vol. 1, No. 9, May, 1916, where the method employed is set forth in detail.) The indices proposed by this method are simply the product obtained by multiplying Transeau's rainfall-evaporation ratio [1] or the ratio of annual rainfall to annual evaporation for the period in question, by the summation index of temperature efficiency for the same period. He employs the physiological indices of temperature as derived from Lehenbauer's [2] results. This system, which takes into account the general principle of temperature minima, optima, and maxima, as related to plant growth, is described in Physiological Researches, volume 1, No. 8, pages 399–420, April, 1916.

A chart is presented in volume 1, No. 9 (ibid.), showing for the average frostless season a climatic zonation of the United States, based on the moisture-temperature indices as thus computed. The chart shows a very high potential climatic efficiency in the Gulf Coast region, where the supply of heat and moisture is great and the frostless season long, with rapid decrease northward and northwestward. The indices range numerically from 23,000 in central Florida to about 200 in portions of the central plateau districts of the West.

The high value of climatic efficiency obtained in the more southern localities by the Livingston method is due largely to the long frostless season in that area and the method used in combining the moisture and temperature factors. By taking the product of the two factors for a given period the resulting values increase rapidly with an increase of either factor and much more rapidly when both factors are raised. Thus, an increase of 100 per cent in one factor elevates the final result by a like amount, while an increase of 100 per cent in both factors results in an indicated climatic efficiency value fourfold greater.

[1] Transeau, E. N., Forests of Eastern America. Amer. Nat. 39: 875–898, 1905.
[2] Lehenbauer, P. A., Growth of maize seedlings in relation to temperature, Phys. Res. 1: 247–288, 1914.

A GRAPHIC SUMMARY OF SEASONAL WORK ON FARM CROPS.

By O. E. BAKER, C. F. BROOKS, and R. G. HAINSWORTH.

[Separate 758, Yearbook, U. S. Dept. Agric., 1917 (pp. 537–589, 90 figs.). Abstracted and discussed.]

"This study contains maps showing the dates when planting, harvesting, and other operations are performed in the culture of the staple crops in different parts of the United States, and also graphs showing the seasonal distribution of labor by 10-day periods on typical farms in several important agricultural regions. Inscriptions under the maps afford information as to the hours of labor per acre required in growing the staple crops in various sections of the country."

Fifty-four maps show the usual dates when the most important operations are performed on winter wheat, spring wheat, winter oats, spring oats, corn, kafir corn, timothy, and clover, alfalfa, cotton, early potatoes, late potatoes (northern commercial crop), sugar beets, field beans, tobacco, Elberta peach, Ben Davis apple, strawberries, and tomatoes.

In preparing these maps, "the dates for each operation were entered from the schedules returned by the township reporters on large county outline maps of the States. The altitude reported on each schedule was indicated also. In making the general maps showing dates by isochronal lines, a strict use of the individual reports was not possible. This is because there is for many crop operations a wide range of dates in the reports received from a county. Such differences are due (1) to the physical conditions, such as temperature, slope, drainage, and soils on each farm; (2) to the individual practice of the farmer; and (3) to the difficulty of estimating for

some crops and operations the dates in a normal or usual season as requested on the schedule. Therefore, where it was reasonable to do so, county averages of the reported dates were used. Such averages sufficed for most of the operations in flat regions, especially for such definite events as the beginning of wheat harvest. Three sets of conditions, however, prevented use of averages for all maps or for all parts of a map, namely, large differences in elevation; two or more periods of planting; and, for certain operations, an extended period during which the work can be carried on. Where the reports from different altitudes showed a well-marked topographic influence a contour map was used as an aid in drawing the isochronal lines. Where there were two or more well-defined planting periods the dates used were the modes or the averages of the most numerous group. Corn, spring oats, and late potatoes had to be treated wholly obscured. Local markets may hasten the harvest of certain crops, such as potatoes, near the large cities."

The maps of the planting and digging of the northern commercial crop of potatoes, particularly the former (fig. 67, reproduced in fig. 1), show well the various factors involved in planting and harvest dates. Early potatoes are generally planted as early as possible, a certain amount of frost risk being taken[1] because of the value of early arrival of the crop on the market. The mean daily temperature at the time of planting is about 45° F.; thus, early potato planting occurs at about the time vegetative activity starts.[2] On this account the map "Early potatoes, date when planting begins" (fig. 63, reproduced in fig. 4, p. 315 above), shows perhaps better than a temperature map the progress of the season northward in the United States." In the case of the northern commercial crop of potatoes, the planting time is of little consequence. In the southern

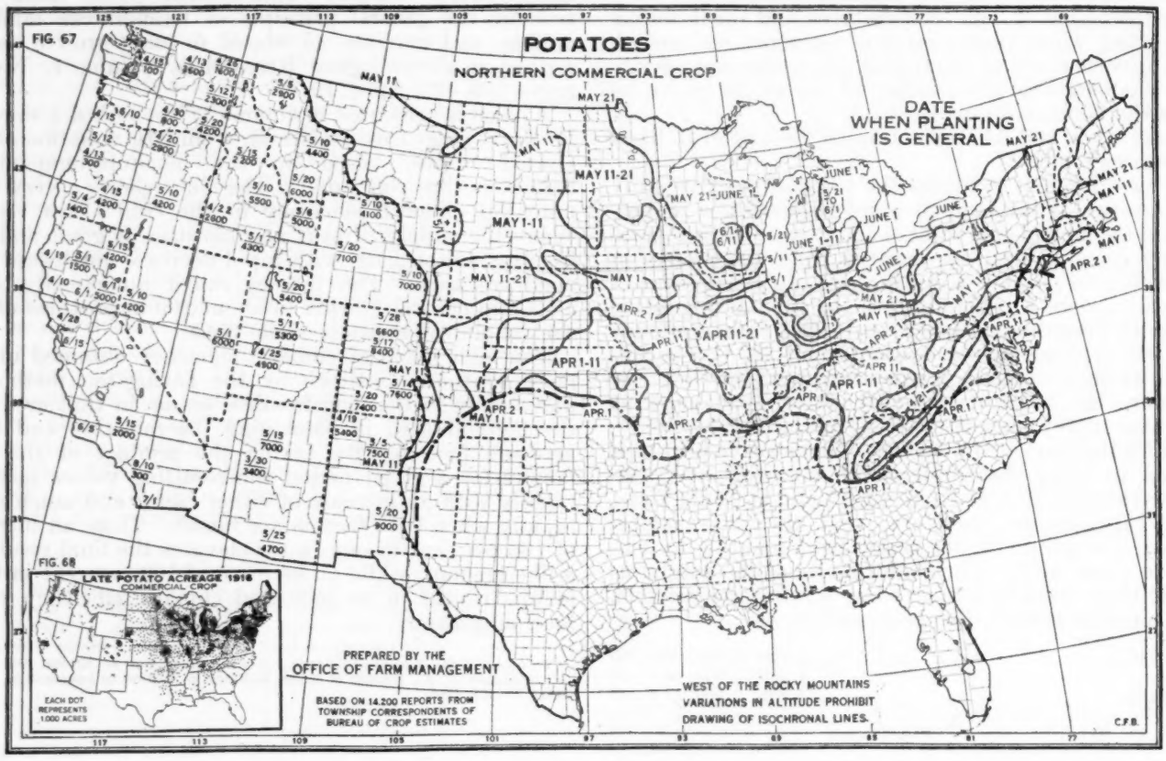

FIG. 1.

in part in this way. Where the operation may be performed during an extended period the modal date was generally used, or the range in dates was shown on the map. In general, the maps show the average of the usual dates when most (not all) farmers perform the crop operation designated.

"The most striking feature of the maps is the northward and upward movement of spring operations and events and the southward and downward progress in autumn. This movement progresses at a rate of approximately one degree of latitude, or 400 feet of altitude, in four days. Local climatic influences of the Great Lakes and of the Atlantic Ocean are evident on almost every map. In operations which may be performed during a long period the maps indicate for the most part only the effect of local competition for labor by other crops, although the underlying control of general climatic conditions is not part of the corn belt there is ample time for potato planting before the mean temperature rises high enough (about 55° F.)[3] for corn planting. In the northern portion of the corn belt, on the contrary, the planting of the large oats crop occupies most of the time between the advent of planting weather and the time when corn can be put in. Thus, while most of the farmers in southern Indiana plant their "late" potatoes in the middle of April, before corn planting, the majority of those in northern Indiana are not putting in their late potatoes until the end of May or early June, after corn planting. "In the Maine, New York, Michigan, Wisconsin, and Minnesota districts [the planting dates are generally earlier, for] the necessity

[1] Cf. Reed, W. G., and Tolley, H. R., "Weather as a business risk in farming," *Geogr. Rev.* 1916, vol. 2, pp. 48–53.

[2] Cf. Kincer, J. B., "Relation between vegetative and frostless periods," Monthly Weather Review, 1919, 47:106–110; and "Temperature influence on planting and harvest dates," pp. 312–313, above.

[3] See pp. 315–317, above.

of digging the crop before the ground freezes limits to a period of a few weeks not only the digging but also the planting of potatoes. Owing to the moderate autumn temperatures along the Lake shores in Michigan, [Ohio], and New York, however, digging may be delayed as late as the latter half of October." This seems to explain why general planting is delayed till early June in such favored localities.

Comparisons of other groups of maps bring out many reasons for the peculiar distribution of dates when various crop operations are performed. In general, the seasonal control is most evident on the maps of the following operations: Beginning of planting of spring wheat, spring oats (fig. 2, p. 314, above), early potatoes (fig. 4, p. 315 above), corn (fig. 6, p. 316, above), and cotton (fig. 8, p. 318, above); and beginning of harvest of wheat (fig. 2), oats (fig. 3), potatoes, cotton, and Elberta peaches.

caught up with the winter wheat. In the week ending June 19 both harvests had advanced north to Kansas and Missouri; in the last week of June winter wheat harvest had advanced to southeastern Virginia, and oats harvest to southeastern north Carolina. A marked delay of two weeks in the Great Plains and of four or five weeks in the East brings attention to the cool, wet spring which delayed planting, and to the cool weather which retarded the development of the grain. As the winter wheat harvest dates, obviously, were not affected by any lateness of spring planting, the harvest advanced northward at the usual rate, although 10 days or more late. * * *

"The warm, dry weather, beginning early in July, on the Great Plains so accelerated the harvests that winter wheat finished only a week late, and spring oats on the usual dates. East of the Mississippi, however, the hot week of July 24 marked the first rapid advance of the

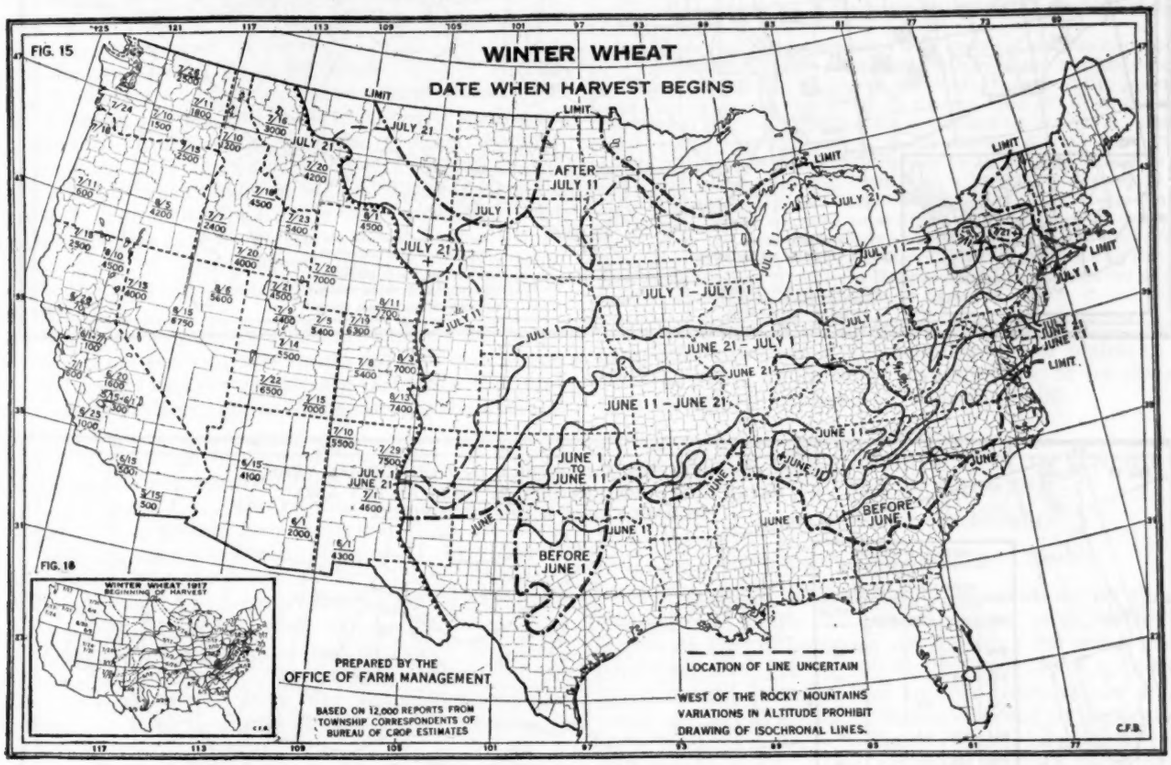
FIG. 15
WINTER WHEAT
DATE WHEN HARVEST BEGINS
LIMIT
JULY 21
AFTER JULY 11
JULY 1
JULY 1 – JULY 11
JUNE 21 – JULY 1
JUNE 11 – JUNE 21
JUNE 1 TO JUNE 11
JULY 11 TO JUNE 21
BEFORE JUNE 1
FIG. 18
WINTER WHEAT 1917 BEGINNING OF HARVEST
PREPARED BY THE OFFICE OF FARM MANAGEMENT
BASED ON 12,000 REPORTS FROM TOWNSHIP CORRESPONDENTS OF BUREAU OF CROP ESTIMATES
LOCATION OF LINE UNCERTAIN
WEST OF THE ROCKY MOUNTAINS VARIATIONS IN ALTITUDE PROHIBIT DRAWING OF ISOCHRONAL LINES.
C.F.B.

FIG. 2.

There are three maps showing the actual progress of the beginning of harvest of winter wheat, spring wheat, and spring oats in 1917, when the line of the harvest front was mapped from telegraphic data each week for farm labor distributors.[4] These maps were discussed in the National Weather and Crop Bulletin, August 28, 1917, pages 2 and 3, from which the following quotations are taken:

"Before the end of May the harvest of winter wheat (fig. 16, in fig. 3) was in progress from southern South Carolina to central Alabama and in central Texas; the spring oats harvest (fig. 36, reproduced in fig. 3) was following about a week later. Warm, wet weather, followed, in the South, by a cool, dry week during the first half of June, brought the oats harvest northward so rapidly that it almost

harvest. In the cool preceding fortnight the winter wheat harvest had advanced from the southwestern to the northwestern corner of Ohio. The hot week brought the spring oats harvest front over the same distances in half the time, so that the spring oats harvest was only 10 days late in the same place where a week earlier the winter wheat harvest had been 21 days late * * *."

One map (fig. 13 reproduced in fig. 4) shows the "date for seeding [winter wheat] which will, in the normal year, reduce or avoid injury by the Hessian fly and probably give a greater yield." The original background of this map is fully discussed by Dr. A. D. Hopkins in his monograph, "Periodical events and natural law as guides to agricultural research and practice" (MONTHLY WEATHER REVIEW, Suppl. 9, 1918, 4 to 40 pp., 24 figs.; see also Scientific Monthly, June, 1919, pp. 496–513). The lines on the fair climatic map showing the beginning of winter wheat

[4] Similar maps were published in the National Weather and Crop Bulletin weekly during the summer of 1918.

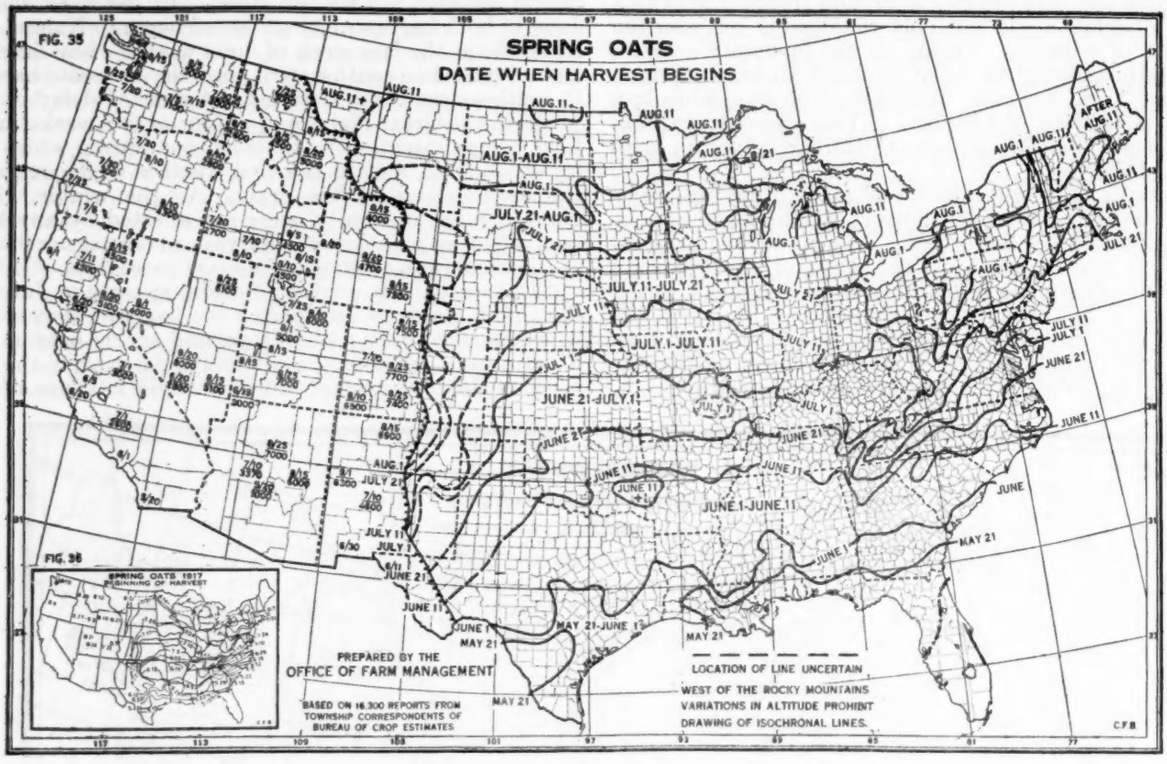
FIG. 35
SPRING OATS
DATE WHEN HARVEST BEGINS
AUG.11
AUG.1-AUG.11
JULY.21-AUG.1
JULY.11-JULY.21
JULY.1-JULY.11
JUNE.21-JULY.1
JUNE.11-JUNE.21
JUNE.1-JUNE.11
MAY.21-JUNE.1
AFTER AUG.11
JULY 21
JULY 11
JULY 1
JUNE 21
JUNE 11
JUNE
MAY 21
FIG. 36
SPRING OATS 1917
BEGINNING OF HARVEST
PREPARED BY THE
OFFICE OF FARM MANAGEMENT
BASED ON 16,300 REPORTS FROM
TOWNSHIP CORRESPONDENTS OF
BUREAU OF CROP ESTIMATES
LOCATION OF LINE UNCERTAIN
WEST OF THE ROCKY MOUNTAINS
VARIATIONS IN ALTITUDE PROHIBIT
DRAWING OF ISOCHRONAL LINES.
C.F.B.

FIG. 3.

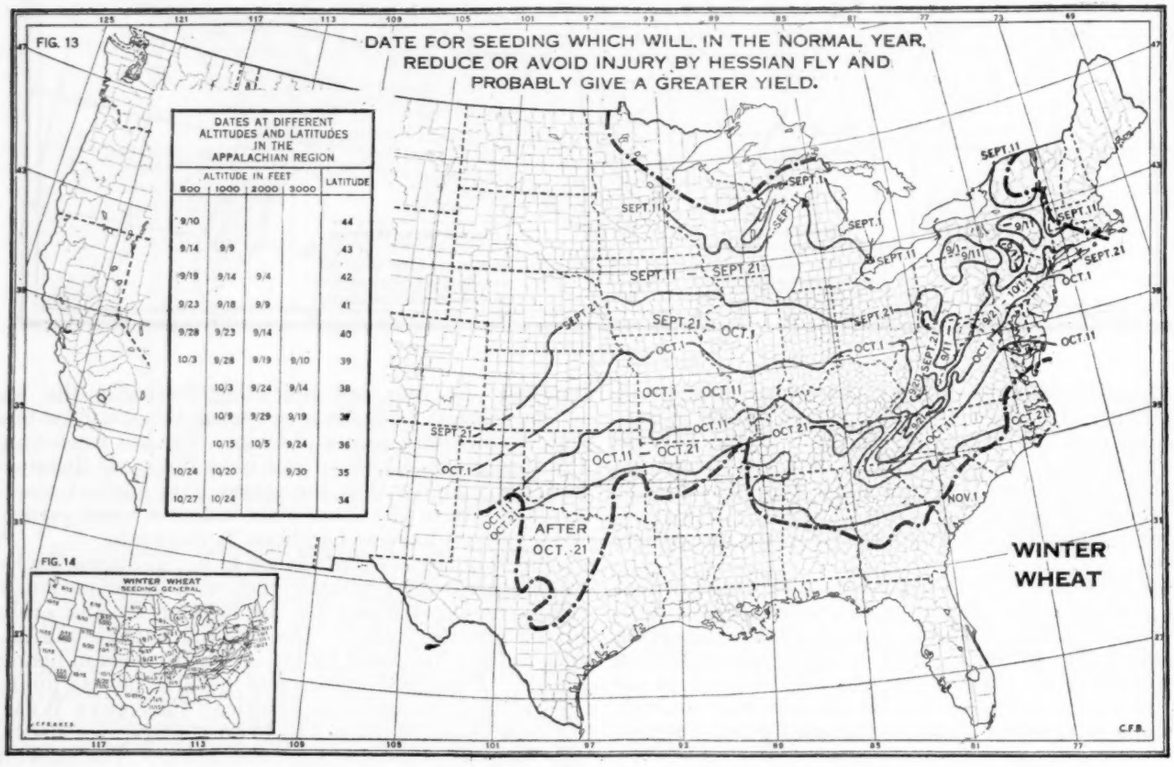
FIG. 13
DATE FOR SEEDING WHICH WILL, IN THE NORMAL YEAR,
REDUCE OR AVOID INJURY BY HESSIAN FLY AND
PROBABLY GIVE A GREATER YIELD.
DATES AT DIFFERENT ALTITUDES AND LATITUDES IN THE APPALACHIAN REGION
ALTITUDE IN FEET
LATITUDE
SEPT.11
SEPT.11 – SEPT.21
SEPT.21 – OCT.1
OCT.1 – OCT.11
OCT.11 – OCT.21
AFTER OCT. 21
NOV.1
WINTER WHEAT
FIG. 14
WINTER WHEAT
SEEDING GENERAL
C.F.B.

FIG. 4.

harvest (fig. 15, reproduced in fig. 2) were used with a new set of dates to make a map of the advance of autumn. Local modifications were necessary to allow for the effects of the Great Lakes and Atlantic Ocean. Such a map may be used as a general basis for "safe" wheat seeding, because the development of the Hessian fly is closely dependent on late-summer and autumn weather.

The lines were dated and modified in "an attempt to correlate the recommendations of the different experiment stations as to the date of seeding winter wheat. The results of experiments in Kansas, Nebraska, Iowa, Indiana, and Ohio show that when the Hessian fly is prevalent the best yields may be expected when the seeding occurs just after the emergence of the last autumn brood of the fly; and when the fly is not numerous, the best time for seeding generally is about a week earlier. In the years when the fly is prevalent the actual dates to be recommended depend on experiments in the fields at the time, so in such years it is necessary to follow closely the recommendations of the State entomologists. Planting in the North depends largely on the season and the labor situation. South of the thirty-ninth parallel and east of southeastern Kansas the autumn is long enough to allow seeding after the average date of emergence of the fly, with the best chance of still securing the maximum yield." The altitude-latitude table inserted in the map represents the reverse of the latitude and altitude rate of progress of winter-wheat harvest, which progresses about a degree of latitude or 400 feet of general altitude in 4 days.

As Dr. Hopkins points out, there are many other ways in which the maps showing the actual dates of operations can be used as a basis for improving farm practice and for determining the best regions for expanding the average of different crops.

Supplementing these isochronal maps, are 17 "dot" maps showing the acreage distribution of the crops mentioned. Two maps show the regions where corn is cut and shocked, and where corn is jerked from standing stalks. Two graphs show the production of early and of late potatoes by date of harvest zones. The applications to farm management and farm labor problems are brought out in detail by graphs showing the hours devoted to different farm operations by 10-day periods throughout the year at seven typical farming regions of the United States. There are three large dot maps showing the distribution of farmers, of farm laborers, and of expenditure for labor.—*C. F. Brooks.*

DUFRÉNOY'S OBSERVATIONS OF THE TEMPERATURES OF PLANTS IN SUNLIGHT AND SHADE.

The difference in the temperature of plants in direct sunshine and in shade, and the action of the pigments in varying the temperature of different colored leaves and plants in sunshine, is shown in a recent article by the French naturalist Mr. J. Dufrénoy, of the biological station at Arachon, in the Revue Générale de Sciences.

He explains the formation of the pigments in plants, and the increase or decrease of pigmentation with varying heat, moisture, and sunshine values, then shows the effect of these different pigments in the absorption of solar energy.

We quote the following from a recent review of this article in the Scientific American Supplement for February 15, 1919:

* * * The solar energy absorbed by the pigments is largely converted into heat. In January at Arachon, on a fine day, the temperature of the plants exposed to the sun exceeds that of the air by from 6° to 8° C. at noon, and by from 12° to 15° C. at 3 p. m.; the amount of this rise in temperature varies according to the color and to the intensity of the pigmentation, so that a difference of more than 1° C. may exist between the yellow and the green leaves of the variegated foliage of a spindle tree, or even between the two borders of a single variegated leaf.

Experiments made in January at Arachon gave the following results: In a variegated leaf of the *Iris pallida* the green portion showed a rise in temperature of 9.8° C. over that of the air against a rise of only 8.5° C. in the yellow portion. Similar observations were made with the red and green leaves of an arbutus, the time being 10 a. m. and the temperature of the air 10° C.; in this case the red leaf showed a rise of 7.5° C. and the green leaf a rise of only 7° C.

* * * * *

In November tests were made at 2 p. m. with red and white arbutus berries, the temperature of the latter being 29.5° C. and that of the red one degree higher.

Finally experiments were made with grapes of various colors placed in sunshine and in shade. The temperature of the red grapes in the sun was 37° C. and 10° C. less in the shade; that of white, green, and amber colored grapes was 34° C. in the sun, and 26° C. in the shade. The time of this last experiment was October 10, at 3 p. m., the temperature of the air being 24° C. in the shade. A second experiment showed that grapes with a dull surface had a temperature of 35.5° C. in the sun, whereas that of those with a bright surface was 34.8° C.

A highly interesting fact is that every rise of 10° C. in the temperature of the organs exposed to sunlight doubles or even trebles the rapidity of the reactions observed—for example, the intensity of respiration is greatly enhanced, more carbon dioxide being liberated.

In fruits exposed to sunlight the plant acids contained are reduced, and the ripening is correspondingly hastened. * * *

These experiments illustrate the difficulty in making comparable records of the temperature of plants in sunshine as made by different investigators, or by the same man at different times.—*J. Warren Smith.*

NOTE ON THE HEATING OF PLANTS IN SUNLIGHT AS A FACTOR IN GROWTH.*

By D. A. SEELEY, Meteorologist.

[Dated: Weather Bureau, Lansing, Mich., May, 1919.]

The results of M. Dufrénoy's observations on the temperature of plants, as quoted above, offer further evidence of the importance of sunshine in plant growth. Differences of 12° to 15° C. (22° to 27° F.), noted by M. Dufrénoy between leaf and air temperature on clear days, are not in excess of those observed by several other investigators at various times. Such large temperature differences must surely produce marked metabolic activities in the plant, not to mention the actinic influences. The fact that under sunshine plants are so much warmer than the air should be given more consideration in studies of the relationship between weather conditions and plant growth. In the past it has been the custom to study air temperature in relation to plant growth without considering the often widely different temperature of the plant itself, especially in sunshine. The "Summation method," by which the excess of air temperature above a given limit is computed, gives widely divergent results when worked out for a given life phase of plants in different years, largely on account of the failure to take into consideration the difference between plant and air temperature. When the sun is shining the air temperature does not register the true thermal con-

* Cf. "Crops and temperature," Abs. in MO. WEA. REV. 1917, 45: 354-359.

125518—19——4

dition of the plant and hence does not furnish an accurate index of growth. Cloudiness and other factors cause variations in the duration and intensity of sunshine, which are only partially reflected by the air temperature, while the plant responds more perfectly.

MEASURING THE TEMPERATURE OF LEAVES.

Mrs. Edith B. Shreve has devised very sensitive electrical apparatus for measuring the surface temperature of leaves and has been making measurements in the desert and mountains near Tucson, Ariz., and the Santa Lucia Mountains in California. She reports that the most outstanding result of these measurements is the rapidity with which the surface temperature of a leaf growing in the open may fluctuate. Changes of from 1 to 3° C. are observed within 20 to 60 seconds. If a moderately strong wind is blowing the change may amount to 5° in 30 seconds. [Momentary changes in the temperature of the passing air are without doubt in part the cause of these fluctuations.]—*Reprinted from Scientific American, Apr. 12, 1919, p. 365.*

ALFALFA GROWING IN WESTERN SOUTH DAKOTA.

By HARLEY N. JOHNSON.

[Dated: Weather Bureau, Rapid City, S. Dak., April, 1919.]

SYNOPSIS.—The climate of western South Dakota is especially favorable for raising alfalfa, as 73 per cent of the annual rainfall of 15 to 20 inches is received during the period from April 1 to September 30, the percentage of sunshine is high, the rate of evaporation is comparatively low, and moderate temperatures usually prevail during the growing season. The soil is deep and rich and retains moisture well. Alfalfa needs considerable moisture while growing, but fair weather while the hay crop is being harvested.

Alfalfa seed is usually produced from the second crop when conditions are such as to retard the maturing of the first hay crop. Alfalfa seed is produced in paying quantities in South Dakota only when there is a comparative shortage in the moisture supply, hence the weather conditions determine whether the second crop shall be cut for hay or left for seed. If there is considerable rainfall, the second crop is usually cut for hay, and a third crop is frequently possible.

As alfalfa hay is damaged by rain when curing, special weather forecasts are issued and widely distributed during harvest. The growing season is usually of sufficient length to mature seed from the second crop, but if it is too dry after the first crop has been harvested, and the growth of the second crop checked, there is danger of frost injury to seed in the early fall. A frost-warning service is therefore maintained and is widely utilized by seed growers.—*J. W. S.*

There are 24 counties in South Dakota west of the Missouri River, comprising 26,266,895 acres, of which, roughly 5 per cent is devoted to the raising of alfalfa. The usual yield is from two to three crops of hay per year, or approximately 3 to 5 tons per acre. Western South Dakota has been producing alfalfa for the past 38 years, the first seed of record being brought from Utah in 1881, and it is now successfully grown in every county and has become the great staple forage crop.

The experience of alfalfa growers, covering a period of a great many years, shows that a semi-arid region is particularly adapted to the raising of alfalfa. From 15 to 20 inches of annual rainfall is usually considered necessary for successful farming operations, without irrigation. However, there are several modifying factors to be taken into consideration in connection with the raising of alfalfa in a region of light rainfall, viz, the seasonal distribution of rainfall (73 per cent of the annual, falls from April to September in western South Dakota); the rate of evaporation; amount of sunshine; temperature; and the qualities of the soil for retaining moisture. The deep rich soil of the farming sections of western South Dakota, the prevalent warm sunshiny weather, and the favorable distribution of precipitation evidently produce the proper combination necessary for its best growth. There is practically no land in western South Dakota, that is susceptible of cultivation, that will not produce alfalfa, and probably 95 per cent of the production is grown without irrigation, the practice of irrigation being limited to a few valleys where the crop is grown almost exclusively for hay. (See fig. 1.)

Three varieties are most extensively grown, viz: Common or mixed varieties, Grim, and Turkestan.

The first step in the process of raising alfalfa is the preparation of the seed bed, which is of vital importance. The ground should be plowed and harrowed, or double disked, then given time (from a month to six weeks) to settle thoroughly before planting the seed. The planting is usually done in the spring, with a drill having a special feed for alfalfa, and is set to sow from 10 to 12 pounds of seed per acre, and to cover the seed from 1 to 1½ inches deep. Just before planting the top crust should be loosened and pulverized by light harrowing, as this will insure a fine soil on the surface for seeding and a firmer soil below for the embedding of of the tap root, which immediately strikes downward after germination of the seed. However, there are many fields of alfalfa where the seed was sown broadcast on unbroken sod and disked in. This method is not advisable as experience has shown that the stand will die out in a few years, although the first two or three years crop may be exceptionally good.

The alfalfa plant is more or less subject to winter-killing, a situation that is practically unpreventable, except where irrigation is practiced. The chief causes of winter killing in the Middle West are: Excessively dry weather in the late fall and winter, and alternate freezing and thawing of the soil. From the first cause the injury is frequently of considerable consequence, as occasionally the fall precipitation is insufficient to supply the soil with moisture necessary to keep the plant alive, and for evaporation. However, this feature is overcome to some extent by an average snowfall of 13.5 inches (Rapid City record) during the months of December, January, and February. The snow blanket affords a protection from the cold and wind, thus eliminating the winter-killing that would otherwise result in an open dry winter with no snow covering. From the second cause the injury is probably greater. The damage from this cause is increased when an excessive amount of precipitation occurs in the late fall. When the soil is saturated with water the alternate freezing and thawing on days when the ground is bare may prove fatal to the plant, due to the fact that the sap rises into the branches on warm days, then freezes when the temperature falls, thus causing an expansion or rupture of the cells of the plant. The average number of freezing and thawing days, with no snow covering, for the three winter months is as follows: December, 10; January, 10; February, 9.

Almost without exception the first crop of alfalfa is utilized for hay. If the season is early and the first crop of hay is matured and cut before June 10, the prospects for two more hay crops are good, but if the first

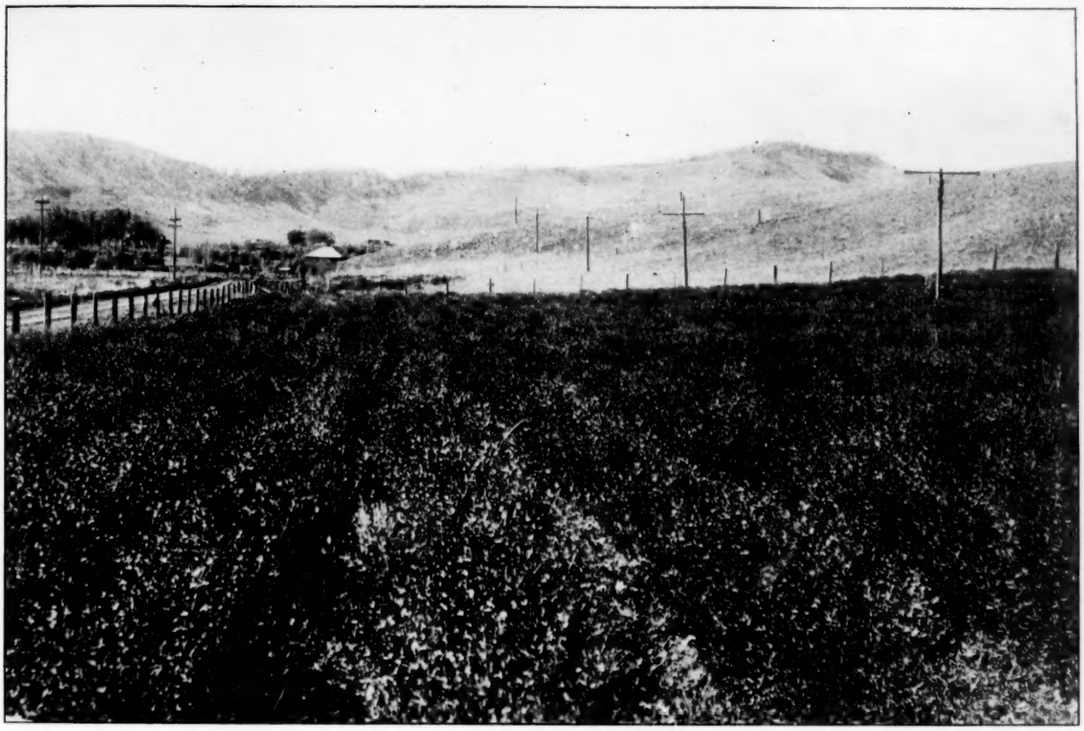

FIG. 1.—Alfalfa in rows, Rapid City, S. Dak.

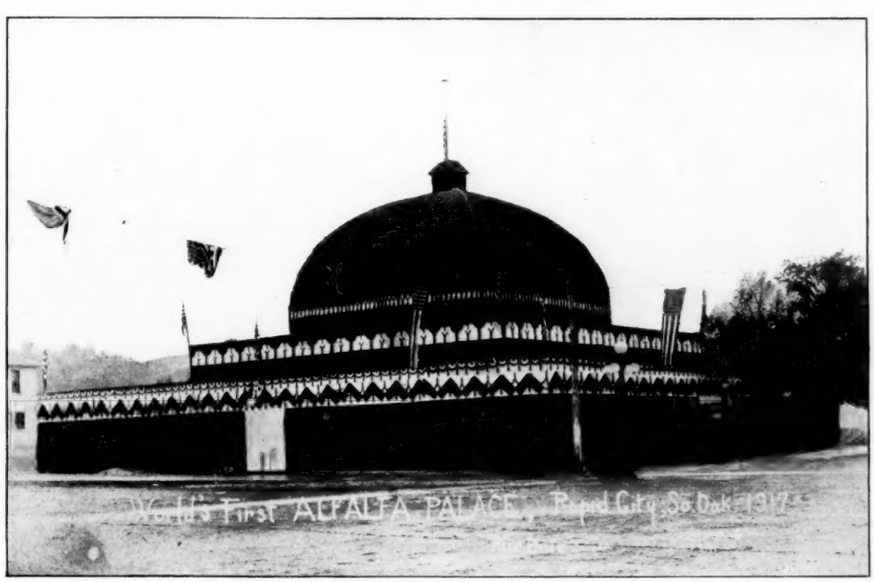

FIG. 2.

J. C. Alter.

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FIGS. 1-3.—Special alfalfa-seed region meteorological station, Deseret, Utah, in 1916, 1917, and 1919.

crop does not mature early the second is left standing to produce seed. The weather conditions determine whether or not the second crop should be utilized for hay or left for a seed crop. It requires from 30 to 40 days under favorable weather conditions to mature a hay crop. The haying season with growers of extensive acreage is practically continuous from the beginning of the first cutting until frost in the fall, and the method of handling by means of improved implements is quite generally employed. The harvesting of alfalfa hay is often seriously interrupted by showers or rainy weather. Much difficulty is experienced in this connection, as alfalfa hay is easily injured by rain, and every effort is made to cure the crop if possible without getting it wet. While the feeding value of hay that has received only a light rain is not materially lessened, it is, nevertheless, discolored and does not sell well on the market. Oftentimes it is impossible to cure the hay without injury from rain, as it requires from 36 to 48 hours of drying weather for the hay to cure, while the average number of rainy days, 0.01 inch or more, during the harvesting season is as follows: June, 13; July, 10; August, 9; September, 6.

One of the essential features of handling the hay is to prevent the loss of the leaves—the most valuable part of the plant—which will occur if left in the field too long after cutting, especially if the hay has been rained on.

Special weather forecasts are issued by the Weather Bureau in the interests of the alfalfa growers of western South Dakota during the haying season, which enables them to determine how much hay can be cut and cured before rain is likely to occur. Arrangements are in effect whereby the forecasts for an extended period of fair or rainy weather are distributed by telephone throughout the alfalfa growing sections. As the great majority of growers have telephones in their homes, the information reaches them without delay. Upon receipt of the forecast for continued fair weather the grower immediately starts cutting and continues until the advent of unfavorable weather. The information and the advantages thus gained by the forecasts of the Weather Bureau are of great value to the grower, and the service as maintained is highly appreciated in this section.

On the great "bench" lands above the creeks is grown, without irrigation, the greater portion of the alfalfa seed raised in western South Dakota. The yield runs from 3 to 8 bushels per acre, and the buyers from the large seed houses come to western South Dakota to buy seed for commercial purposes. The seed is eagerly sought on the market and commands a price considerably above the average on account of its superior qualities. In many cases the returns from the production of the clear, golden colored, acclimated seed, which has demonstrated its superior ability to withstand adverse weather conditions, has more than paid for the land on which it was produced. Alfalfa seed is produced in paying quantities only when there is a comparative shortage in the moisture supply. Heavy rains during the blooming period are injurious to the seed crop, and for the finest quality of seed the weather should be dry from blooming time until after the harvesting of the seed. Alfalfa seed development requires a hot, dry season, and in order that the crop may mature during such periods, the second crop is generally utilized for the growing of seed. If after the first cutting of hay precipitation occurs in sufficient quantities to give the second crop a good start very little moisture is required thereafter, although the time necessary to mature a seed crop is about twice that required for a hay crop, or from 70 to 90 days. Should the weather be unusually dry in June and the second crop delayed in getting a start, there is danger of injury to the seed by frost in the early fall. However, the growing season is usually of sufficient length to permit the maturing of the seed crop.

A frost-warning service, under the supervision of the district forecaster at Chicago, Ill., is maintained by the Weather Bureau in the interests of the seed growers. Upon receipt of frost or low temperature warnings the local office immediately takes action to make a thorough distribution of the warnings by telephone. The arrangements for distribution are practically the same as for the fair weather forecasts referred to above. The distribution is made over almost every rural telephone line in this section of the State. A special ring is given for "weather," whereupon some member of the grower's family copies the report, and action is then taken accordingly. The protection of the seed crop from frost is sometimes a difficult problem. If the crop is late and the frost comes early in the autumn, the seed will be too green to harvest, even though the grower is warned of coming frost. However, this difficulty is overcome to some extent by some of the more progressive growers, who have made a study of, and experimented with, this feature of alfalfa raising. When the frost warnings are received from the Weather Bureau, the grower immediately cuts his green seed crop with a self binder and puts the bundles in narrow ricks two bundles wide, with the heads inside and the butts outside. The moisture escapes through the butts and the seed dries and thrashes out a bright natural color, very much the same as if left to ripen in the field. The narrow rick prevents heating.

To insure the greatest quantity of good seed the alfalfa is harvested when from one-half to three-fourths of the pods have turned brown. Many inexperienced growers cut their seed too green.

Various methods of harvesting are employed, the mowing machine, self-rake reaper, self-binder, and header are used, special care being taken to lose as little seed as possible by shattering while handling. A thin stand is considered best for the production of seed, and the practice of growing alfalfa in rows about 3 feet apart is recognized as advisable, as this affords a means by which the plants can be cultivated and thinned, if necessary.

The importance of the alfalfa seed crop in this section is of considerable consequence, as is evidenced by the fact that the supply is insufficient to meet the demands, although several trainloads of seed are marketed from western South Dakota each good seed year.

ALFALFA SEED GROWING AND THE WEATHER, IN UTAH.

By J. CECIL ALTER, Meteorologist.

[Dated: Weather Bureau, Salt Lake City, Utah, June 16, 1919.]

SYNOPSIS.—The first crop of alfalfa is usually cut for hay in Utah, and the second crop is allowed to go to seed. The seed crop should have sufficient moisture during its early growth to produce a vigorous, healthy plant, but the weather should be dry and not too warm while the plants are in bloom. The dry spell must not be too extended, however, as the seed must have sufficient moisture while setting to give it size and weight. Definite comparisons with yield in Utah show that the spring temperature should average from 3° to 5° F. a day above the normal, and from 2° to 4° F. a day below the normal during the summer months, for best results.

It takes nearly twice as long to grow and mature a seed crop as it does a hay crop. Seed is usually ready for harvest in Utah one to two weeks in advance of the average killing frost date.

As a temperature of 26° to 28° F. in the foliage will seriously damage partially ripe and unripe seed burrs, the frost and minimum temperature forecasts at seed harvest time are of especial importance. The usual practice is to cut as large an area as possible on the receipt of frost warnings, but as the first cold period is often followed by several weeks of fine ripening weather, and as the value of the seed is said to increase at the rate of nearly $5 an acre each 24 hours when ripening, efforts should be made to protect the plants from frost damage without cutting.—*J. W. S.*

To every alfalfa grower comes the question, Shall the crop be cut for hay or left for seed? To the central and eastern States grower it arises but rarely, while in the interior western third of the United States, where the altitude, aridity, sunshine, and summer warmth are especially favorable for seed development in average years, the question is perennial.

Owing to the great demand for seed, its production is imperative whenever meteorological conditions will permit, the climate being the limiting factor generally, and the current weather being the major control affecting any season's yield. When droughty conditions threaten the life of the alfalfa plant, nature aims to prevent the destruction of the species apparently by the prolific production of seed; it is not produced in large quantities under other conditions.

Seed crops are matured more or less regularly in all parts of the United States, excepting the extreme eastern coast, but the certainty of the crop and the security of the industry are greatest in the plateau States. A crop is grown in the Central States principally when the corn crop fails, due to drought, the yield running from 2 to 3 bushels per acre as a rule. In the interior western States yields ranging from 4 to 6 bushels per acre on the average, and as much as 8 to 10 bushels over wide areas, are produced about 4 seasons out of 5 as a rule.

The general conditions of soil, topography, and climate in the seed producing regions of the West are very similar to those of the established seed producing regions of the Old World, and it must be assumed from the exacting demands of the crop that seed growing can not be regarded as a stable industry outside of such areas. The failures of the crop in Utah, for instance, which is a leading seed producer, are due principally to grasshoppers and weevils, though such accidental causes as shortage of irrigation water, excessive rains, desiccating winds at blossom time, and untimely spring or autumn frosts are sometimes reported.

Alfalfa, when considered for seed, should have an abundance of precipitation until near cutting time of the first hay crop; the second growth, which is usually the seed crop, should have a moderate supply during its early growth, or just sufficient to produce a vigorous, healthy plant; there should be no heavy rains thereafter until the bloom has fallen. A very favorable normal distribution of precipitation occurs in Utah, where the season is wet until the end of May, and quite dry thereafter, thus giving the first growth of alfalfa sufficient moisture to produce unlimited development and growth of the root system, and provide the necessary physical vigor for bringing on the seed crop. More especially, however, does this heavy spring precipitation provide a storage of moisture in the soil for the early use of the seed crop.

There must be a rapid and early rise of springtime temperatures, without setbacks, to get the first or hay crop out of the way and get the seed crop started off in good season. Such seasons have produced yields above the average usually, especially if the ensuing summers were moderately cool and not too dry. Deficient yields have very frequently been associated with late, backward springs and much wet weather.

The summer drought, along about seed setting and ripening time, must not be too severe, as there must be ample moisture to fill the seeds out and give them weight. Also, heavy rains must not wash away the pollen, neither must rainy periods interfere greatly with the work of bees. If the yield is dependent on natural precipitation, studies made in Utah would indicate that 2 or 3 inches of precipitation a month from March to May, inclusive, are desirable, with about one-half an inch per month, thereafter in light showers.

The summer must not be too warm at blossom time, as the wilting and blighting of the bloom are readily accomplished by sustained high wind and a deficiency of moisture occurring inopportunely. Average monthly maximum temperatures above 90° (F.) in the months of blossoming are unfavorable; and a short period of temperatures about 100° F., when moisture is deficient, have resulted in light yields.

Broadly speaking, the month in which alfalfa starts its growth in spring, should have a mean temperature normally of about 40° (F.); about 48° (F.) in the next month for best development; 56° (F.) in the next month; and about 65° (F.) in the month during which the first hay crop is taken, these being approximately the optimum figures prevailing in the Utah seed regions. They are for March, April, May, and June. The crop matures in months of similar temperatures but of different name, in both cooler and warmer climates generally.

The seed crop follows in months with mean temperatures, which are considered approximately the optimum, of 70° (F.) to 75° (F.), in July and August, these being the blossoming and seeding months in Utah. Statistical studies show that this period may be followed by either warmer or cooler periods, for the work of harvesting, though if the mean temperature of the following month, September, be 60° (F.) or lower, there is a strong probability of frost damage before the average harvest is completed. Definite comparisons with yields in several years and localities show that mean spring temperatures from 3° to 5° above normal in Utah are necessary for securing a yield of seed above the average, in regions where there is normally but scant time to mature a good crop of hay and its subsequent seed crop, between the average dates of spring and autumn killing frosts. Such spring seasons should be followed by summers from 2° (F) to 4° (F.) below normal, to give a slow and gradual plant growth, and a consequent better and more extensive setting of the seed.

Studies of killing frost data show that the seasons are longer and safer on the gently sloping or foothill lands than in the broad open flat lands, the increase in the length of the summer frost-free season amounting to from two to three weeks. Also, that the actual altitude, within certain limits, exerts less influence on the average frost dates than the immediate surface configuration or topography.

The most favorable altitudes in Utah for seed are from 4,300 to 5,500 feet above sea level, where the second crop is saved for seed. Above 5,000 feet on the broad open plains where frost formation is not retarded by air movement regularly, the seed crop must be started off very promptly to escape the average dates of autumn frosts. At altitudes of 5,500 to 6,500 feet, where seed is usually grown from the first cutting, the starting of the seed crop is regulated by close pasturing frequently. The starting of the second crop for seed may be regulated by the time of cutting the first crop, and all development and cutting dates can be forced or delayed somewhat by withholding or applying irrigation water and also by proper cultivation to conserve moisture while in stubble stage.

The average cutting dates vary with the accumulations of excesses or deficiencies in temperature—that is, with the amount of the retardation or advancement of the season in any year. This is determined by adding the daily temperature departures from normal daily. The average maturing season for the principal seed producing regions in Utah is about 80 days, the first cutting coming about June 15 to 20 in average years. Forty days are then required, as a rule, to reach the early blossom stage or cutting time for hay, about July 25 to 30. Forty additional days in an average year for maturing the seed brings the harvest about September 4 to 9, a week or two before the average date of first killing frost in autumn. It takes a little longer to mature at the higher altitudes and in cooler seasons, but an excess of moisture is much more potent in prolonging the growing season.

Grasshoppers are usually more numerous in the fields during a droughty season, when feed elsewhere is scarce; and weevils are more predatory in late spring seasons, when it is cold and wet. The weevil may be very successfully combated by cutting the first crop as early as may be necessary and working the field energetically with brush and wire drags and other implements, if the weather is dry, to bury the larvæ. If the weevil is not thus covered in the dust mulch the seed crop will probably be retarded as much as several weeks, depending on the amount of moisture and the quantity of the weevils. If the spring be greatly retarded, and much loss of hay would result in an early cutting, heavy pasturing may be substituted, or spraying with solutions of arsenate of lead or zinc arsenite, as recommended by the United States Bureau of Entomology officials in Utah.

To avoid or mitigate injury from the occasional early autumn frost, in case the seed is still in the field at this time, as is often the case in Utah, the commonest practice is to cut all the seed practicable upon the issuance of the frost warning and irrigate such fields as may not be ready to cut and as have water available. The partially ripened seed will mature after cutting, though since it is adding many pounds per acre per day in weight and improving steadily in quality, only those portions of the non-irrigable fields most subject to frost should be cut. In the pile, shock, or windrow there are fewer seed pods exposed to the frost; though those that are exposed will be injured about the same as if left standing. The practicability of cutting seed prior to frost was first stated in Utah by Mr. George McCune, of Mills, Utah, now special meteorological observer, who, as spokesman for a number of growers, requested the first alfalfa seed frost-warning service, which was begun in 1913.

The use of irrigation water to ward off frost injury or formation has been fairly well demonstrated in many fields and seed regions, and is rapidly growing in favor, wherever the water is available. Some growers conserve water for this special use by withholding some that might be applied a short time earlier to make the seed fill out properly. In all cases the ditches must not be allowed to become useless and every effort made to provide a little water for use on the afternoon or evening prior to the expected frost in the fields which can best be irrigated or which are most retarded in growth. The watering will prolong the growing season and retard the ripening of the seed somewhat, but it usually makes a greater number of pounds in the yield, and, by warding off a light frost, the quality is undoubtedly improved.

Early autumn frosts are very often followed, in Utah, by several weeks of fine weather, at least enough time in which to mature and harvest the seed crop, therefore every effort must be made to protect the crop against this first frost. The probability is that the first frost will not be as severe nor as hard to combat as the later frosts.

There has been some experimental smudging, that is, producing a small amount of heat and a great deal of a smoke and steam or moisture blanket to prevent the loss of heat by radiation, by burning wet straw or manure along the windward side of large seed areas; and in view of the certain amount of success of this form of protection for the fruit orchards of California, Oregon, Idaho, Ohio, parts of Utah and other States, the practice warrants every possible consideration in the alfalfa seed growing regions, especially where it can be made a community affair.

Every effort has been made to correlate the weather conditions in the Utah alfalfa seed growing regions with general conditions shown on the daily weather maps from which the daily weather forecasts are made by the district and national forecastser, for the purpose of amplifying these forecasts for the several individual localities, and for estimating as accurately as possible the probable minimum temperature that may be expected on the following morning.

Special meteorological stations are maintained in a few places, where the need has seemed to be greatest, from which weather reports are received by telegraph daily at Salt Lake City from the time the first ripe seed appear until the last has been harvested. The State forecasts and the amplifications are made available at government expense to every seed growing region where the growers wish to make use of them.

Cooperative weather stations are located conveniently to practically all the seed producing regions of the State, and thus the climates of these regions have become more or less familiar, through the Bureau's publications. The special alfalfa seed region meteorological Station at Deseret, Utah, in charge of Mr. Samuel W. Western, for the past five years (see figs. 1, 2, and 3), shows that temperatures in the alfalfa foliage, in which the special station is located, is about 3° cooler on the average than in the ordinary weather station exposure such as Mr. Western has had on his farmstead for the past twenty years. On cloudy mornings the temperature in the alfalfa foliage will not differ greatly from that in the ordinary thermometer shelter. In general, the colder it is the greater has been the difference between these readings; that is if the general temperatures are in the lower forties the difference will be less than if general

values are in the lower thirties. When temperatures of slightly above freezing occurred in the regular cooperative station, temperatures 6° or 8° lower have occurred in the special station shelter in the alfalfa foliage.

A thermograph has been exposed in this special alfalfa station, as shown in the accompanying photograph, from the records of which the duration of the cold has been determined. This does not vary greatly from the hourly march of temperature and the duration of both the high and the low temperatures as shown on thermograph records at Salt Lake City, so far as the records have been obtained for study. The principal feature of this, however, is that the cold occurs just prior to sunrise, and that the damaging values are usually of rather short duration. Hence smudging as a frost prevention need not begin until toward morning, nor need it continue long, the time being dependent entirely on the temperatures recorded in the region at the time. In general, on a clear night, when a minimum temperature of 25° (F.) is reached, the thermograph shows that the temperature was below 30° (F.) not to exceed two hours. This value, however, varies somewhat on different nights, depending principally on the amount of clouds and wind. Temperatures of 32° (F.) in the foliage have resulted in some damage; temperatures of 30° (F.) usually cause considerable damage.

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Hanzlik, St[anislav]. Die Schwankungen der atmosphärischen Durchsichtigkeit nach den Sonnenscheinregistrierungen in Prag. p. 52–53. (Jan./Feb.)

Sassenfeld, Max. Temperaturbeobachtungen in verschiedenen Höhen des Münsterturmes zu Ulm. p. 53–55. (Jan./Feb.)

Schanz, Fritz. Höhensonne. p. 56–57. (Jan./Feb.) [Extract from a paper in Strahlentherapie dealing with sunshine at high altitudes and its therapeutic qualities.]

Klengel, Friedrich. Wintertypen auf Grund von Pentadenmitteln der Temperatur. p. 65–74. (März/Apr.)

Emden, R[obert]. Beiträge zur Thermodynamik der Atmosphäre. p. 74–78. (März/Apr.) [Continuation.]

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Ångström, Anders. Über die Abkühlung der Wasseroberflächen durch Strahlung. p. 90–93. (März/Apr.)

Süring, R[einhard]. Nachruf auf Rudolf Fuess. p. 93–94. (März/Apr.)

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Wiese, B. Untersuchung des Kälteeinbruchs vom 7. bis 8. Februar 1917. p. 132–142. (Mai/Juni.)

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Schmauss, A[ugust]. Randbemerkungen I. p. 181–187. (July/Aug.) [Miscellaneous meteorological notes.]

Kreisle, Martha v. Über Anomalien der Temperatur zu Wien. p. 187–190. (Juli/Aug.)

Hergesell, H[ugo]. Nachruf auf Richard Assmann. p. 191–192. (Juli/Aug.)

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Gallenkamp, W. Messungen der photochemischen Intensität des Himmels mit dem Skalenphotometer. p. 209–217. (Sept./Okt.)

Kerner, Fritz v. Regenprofile durch Dalmatien. p. 217–224. (Sept./Okt.)

Defant, A[lbert]. Die nächtliche Abkühlung der unteren Luftschichten und der Erdoberfläche in Abhängigkeit vom Wasserdampfgehalt der Atmosphäre. p. 224–245.) (Sept./Okt.)

Wegener, Alfred. Einige Hauptzüge aus der Natur der Tromben. p. 245–249. (Sept./Okt.)

Hennig, Rich[ard]. Die Niederschlags- und Gewitterverhältnisse in Kurland. p. 249–255. (Sept./Okt.)

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Sassenfeld, Max. Reif und Rauhreif in Württemberg. p. 256–259. (Sept./Okt.)

Exner, F[elix] M. v. Über den Massenaustausch bei ungeordneten Strömungen in freier Luft und im Wasser. Bericht über zwei Abhandlungen von Wilh. Schmidt. p. 265–269. (Nov./Dez.)

Mercanton, P[aul] L[ouis]. Schneefälle und Schneedecke an der St. Bernhard-Strasse (Tal von Entremonts) im Wallis von 1904 bis 1913. p. 269–272. (Nov./Dez.)

Hann, J[ulius] v. Die jährliche Periode der halbtägigen Luftdruckschwankung. p. 272–276. (Nov./Dez.)

Liznar, J[oseph]. Über die Berechnung grösserer Höhenunterschiede mit Hilfe der barometrischen Höhenformel von Babinet, E. Alt und einer durch Vereinigung beider sich ergebenden neuen Formel. p. 276–280. (Nov./Dez.)

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Hann, J[ulius] v. Zum Klima von Java. p. 295–296. (Nov./Dez.)

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Bradtke, F. Formel für die Abhängigkeit der mittleren Windgeschwindigkeit von der Höhe nach den Hellmannschen Versuchen. p. 313–315. (Nov./Dez.)

Láska, V. Über die Abhängigkeit der Windgeschwinigkeit von der Höhe. p. 315–316. (Nov./Dez.)

Boll, K. "Ultra-Cirren." p. 316–317. (Nov./Dez.)

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Greim, Georg. Chr. Schultheiss. p. 28–29. (Jan./Feb.) [Obituary.]

Hann, J[ulius] v. Ad. Schmidt, Zur dritteltägigen Luftdruckschwankung. p. 29. (Jan./Feb.)

Schoy, Carl. Über eine Methode zur Berechnung der möglichen Sonnenscheindauer. p. 30–33. (Jan./Feb.)

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SPECIAL OBSERVATIONS.

HALO PHENOMENA OBSERVED DURING MAY, 1919.

By WILLIS RAY GREGG, Meteorologist.

Station.	Altitude.	Latitude.	Longitude.	Date.	Form observed.	Time of—		Theodolite readings.					
						Beginning.	Ending.	Time.	Radius inside.	Radius outside.	Length of arc.	Distance from sun or moon.	Altitude of sun or moon.
	m.	° ′	° ′						°	°	°	°	°
Broken Arrow, Okla.*	233	36 02	95 49	14	Solar halo, 22°	7:30 a. m.	9:45 a. m.	7:45 a. m.	22	23	360		28
				15	Solar halo, 22°	7:00 a. m.	7:02 a. m.						
				15	Parhelion, 22°, right	7:00 a. m.	7:02 a. m.						
				15	Solar halo, 22°	10:45 a. m.	11:40 a. m.						
				15	Solar halo, 22°	4:12 p. m.	4:24 p. m.						
				16	Lunar halo, 22°	1:00 a. m.	3:20 a. m.						
				16	Paraselene, 22°, right	1:00 a. m.	3:20 a. m.						
				16	Paraselene, 22°, left	1:00 a. m.	3:20 a. m.						
				23	Solar halo, 22°	8:10 a. m.	8:25 a. m.	8:17 a. m.					35
				24	Solar halo, 22°	8:50 a. m.	9:30 a. m.	9:07 a. m.			270		44
				24	Solar halo, 22°	1:34 p. m.	1:38 p. m.				270		
				25	Solar halo, 22°	3:30 p. m.	4:15 p. m.						
Canton, N. Y.	137	44 36	75 10	1	Solar halo, 22°	6:50 a. m.	10:30 a. m.						
				3	Solar halo, 22°	4:30 p. m.							
				4	Solar halo, 22°	4:20 p. m.	4:50 p. m.						
				6	Solar halo, 22°	12:00 m.	12:10 p. m.						
				15	Solar halo, 22°	11:20 a. m.	12:30 p. m.						
				16	Solar halo, 22°	8:20 a. m.							
				19	Solar halo, 22°	9:45 a. m.	10:50 a. m.						
				20	Solar halo, 22°	7:00 a. m.	10:00 a. m.						
				27	Solar halo, 22°	6:37 a. m.	10:00 a. m.						
				27	Solar halo, 46°	6:45 a. m.	10:00 a. m.						
Cincinnati, Ohio	191	39 06	84 30	3	Solar halo, 22°	10:20 a. m.	11:40 a. m.						
				19	Solar halo, 22°	9:20 a. m.	11:15 a. m.						
				26	Parhelion, 22°, right	5:30 p. m.	6:00 p. m.						
				26	Parhelion, 22°, left	5:30 p. m.	6:00 p. m.						
Dayton, Ohio	274	39 46	84 10	3	Solar halo, 22°	10:30 a. m.	10:50 a. m.						
				15	Solar halo, 22°	9:45 a. m.	10:15 a. m.						
				18	Solar halo, 22°	5:15 p. m.	5:30 p. m.						
				19	Solar halo, 22°	9:15 a. m.	9:45 a. m.						
Drexel, Nebr.*	396	41 20	96 16	4	Solar halo, 22°	12:20 p. m.	1:30 p. m.	12:35 p. m.	22.5	23	360		64.5
				7	Solar halo, 22°	5:48 a. m.	7:30 a. m.	6:00 a. m.	22	23	192		6
				7	Solar haol, 22°	8:35 a. m.	11:45 a. m.	8:58 a. m.	22	23	360		41
				10	Solar halo, 22°	12:00 m.	2:30 p. m.	12:40 p. m.	22	23	360		65
				10	Solar halo, 46°	12:20 p. m.	12:50 p. m.	12:40 p. m.	44	46	15		65
				23	Solar halo, 22°	12:15 p. m.	2:00 p. m.	12:45 p. m.	22	23	360		69
Ellendale, N. Dak.*	444	45 59	98 34	17	Solar halo, 22°	12:20 p. m.	2:45 p. m	12:30 p. m.	22	24	360		63.5
				20	Solar halo, 22°	3:05 p.m.	3:30 p. m.	3:10 p. m.	22	23	75		46
Groesbeck, Tex.*	141	31 30	96 28	3	Solar halo, 22°	12:08 p. m.	12:52 p. m.	12:40 p. m.	22	23.5	360		74
				11	Solar halo, 22°	5:50 p. m.	Sunset.						
				11	Lunar halo, 22°	7:55 p. m.	D. N., a.						
				12	Solar halo, 22°	6:40 a. m.	10:18 a. m.	6:55 a. m.	22	23.5	195		16
				12	Parhelion, 22°, right	6:40 a. m.	9:57 a. m.	6:55 a. m.	22	24	2	22	16
				12	Parhelion, 22°, left	6:40 a. m.	9:41 a. m.	6:55 a. m.	21.5	24	2.5	21.5	16
				12	Upper tangent arc	6:40 a. m.	6:49 a. m.	7:12 a. m.	22	23	25	22	20
				12	Solar halo, 46°	7:00 a. m.	7:44 a. m.	7:02 a. m.	45.5	47.5	40		18.5
				13	Lunar halo, 22°	9:25 p. m.	9:55 p. m.						
				17	Solar halo, 22°	12:34 p. m.	1:31 p. m.	12:40 p. m.	21.5	23.5	360		74.5
Leesburg, Ga.*	85	31 47	84 14	1	Solar halo, 22°	12:55 p. m.	3:45 p. m.	1:08 p. m.	22		300		61
				4	Solar halo, 22°	3:15 p. m.	5:30 p. m.	3:15 p. m.	22		300		
				4	Lunar halo, 22°	7:05 p. m.	9:00 p. m.	7:25 p. m.	22		360		
				8	Solar halo, 22°	1:45 p. m.	3:30 p. m.	2:12 p. m.	22		360		
				8	Lunar halo, 22°	7:05 p. m.	D. N.	9:00 p. m.	22		360		
				9	Lunar halo, 22°	8:40 p. m.	D. N.	9:00 p. m.	22		360		
				12	Solar halo, 22°	11:52 a. m.	2:15 p. m.	12:05 p. m.	22		150		
				13	Solar halo, 22°	1:41 p. m.	1:56 p. m.	1:41 p. m.	22		180		
				16	Solar halo, 22°	5:45 p. m.	6:25 p. m.	5:45 p. m.	22		300		17
				16	Parhelion, 22°, right	5:45 p. m.	6:25 p. m.	5:45 p. m.					17
				16	Parhelion, 22°, left	5:45 p. m.	6:25 p. m.	5:45 p. m.					17
				16	Lunar halo, 22°	9:00 p. m.	D. N.	9:00 p. m.	22		200		
				18	Solar halo, 22°	6:10 p. m.	6:13 p. m.	6:10 p. m.			10		
				19	Solar halo, 22°	5:25 a. m.	8:05 a. m.	6:10 a. m.	22		180		20
				19	Parhelion, 22°, right	5:25 a. m.	6:20 a. m.	6:10 a. m.				23	20
				19	Parhelion, 22°, left	5:25 a. m.	6:15 a. m.	6:10 a. m.				22.5	20
				20	Solar halo, 22°	8:15 a. m.	8:47 a. m.	8:15 a. m.	22		50		45
				24	Solar halo, 22°	5:23 p. m.	5:45 p. m.	5:30 p. m.	22		165		
				26	Solar halo, 22°	6:54 a. m.	11:25 a. m.	7:05 a. m.	22		120		28
				27	Solar halo, 22°	9:15 a. m.	3:55 p. m.	3:22 p. m.	22		360		36.5
				28	Solar halo, 22°	8:35 a. m.	10:00 a. m.	9:10 a. m.	22		360		55.5
				28	Parhelion, 22°, left	5:50 p. m.	6:15 p. m.	6:00 p. m.				22.5	17
				29	Solar halo, 22°	12:00 m.	12:20 p. m.	12:03 p. m.	22		180		
Madison, Wis.	297	43 05	89 23	2	Solar halo, 22°	9:00 a. m.	11:00 a. m.						
				5	Solar halo, 22°	1:30 p. m.	2:15 p. m.						
				5	Parhelion, 22°, left	5:45 p. m.	6:05 p. m.						
				8	Solar halo, 22°	7:40 a. m.							
				8	Lunar halo, 22°	8:15 p. m.	D. N., p.						
				9	Solar halo, 22°	5:30 p. m.							
				9	Parhelion, 22°, right	6:20 p. m.	6:30 p. m.						
				12	Solar halo, 22°	5:50 a. m.	6:55 p. m.						
				12	Parhelion, 22°, right	5:40 a. m.	9:30 a. m.						
				12	Parhelion, 22° left	5:40 a. m.	9:30 a. m.						
				12	Solar halo, 46°	6:04 a. m.	9:30 a. m.						
				12	Lunar halo, 22°	7:30 p. m.	D. N. p.						
				17	Solar halo, 22°	5:20 p. m.	6:40 p. m.						
				17	Parhelion, 22°, right	6:30 p. m.	6:40 p. m.						
				18	Solar halo, 22°	10:15 a. m.	5:00 p. m.						
				19	Solar halo, 22°	7:15 a. m.							
				19	Upper tangent arc	7:30 a. m.							
				20	Solar halo, 22°	5:30 a. m.	7:45 a. m.						
				23	Solar halo, 22°	5:20 p. m.	6:15 p. m.						
				27	Solar halo, 22°	7:50 a. m.	2:00 p. m.						
				31	Solar halo, 22°	11:45 a. m.							

*Aerological station.

Halo phenomena observed during May, 1919—Continued.

Station.	Altitude.	Latitude.	Longitude.	Date.	Form observed.	Time of—		Theodolite readings.					
						Beginning.	Ending.	Time.	Radius inside.	Radius outside.	Length of arc.	Distance from sun or moon.	Altitude of sun or moon.
	m.	° ′	° ′						°	°	°	°	°
Nashville, Tenn	166	36 10	86 47	4	Parhelion, 22°, right	5:45 p. m.	6:00 p.m.	5:50 p. m.					
				12	Solar halo, 22°	9:00 a. m.	8:40 p. m.	9:05 a. m.					
				13	Solar halo, 22°	8:00 a. m.	10:30 a. m.	8:15 a. m.					
				19	Solar halo, 22°	6:20 a. m.	11:40 a. m.	9:30 a. m.					
				26	Solar halo, 22°	3:00 p. m.	4:00 p. m.	3:10 p. m.					
Royal Center, Ind.*	225	40 53	86 29	12	Solar halo, 22°	8:03 a. m.	9:30 a. m.				180		
				12	Solar halo, 22°	12:18 p. m.	2:30 p. m.	12:35 p. m.	21.8	22.7	360	22	64.5
				26	Solar halo, 22°	7:10 a. m.	7:30 a. m.				180		
				26	Solar halo, 22°	3:30 p. m.	4:45 p. m.				360		
Tatoosh Island, Wash	26	48 23	124 44	1	Solar halo, 22°	3:04 p. m.	5:32 p. m.						
				1	Parhelion, 22°, right	3:04 p. m.	4:50 p. m.						
				1	Parhelion, 22°, left	3:02 p. m.	4:50 p. m.						
				8	Solar halo, 22°	12:30 p. m.	4:55 p. m.						
				9	Solar halo, 22°	5:17 a. m.	5:37 a. m.						
				9	Parhelion, 22°, left	5:25 a. m.	5:40 a. m.						
				10	Solar halo, 22°	6:47 a. m.	7:00 a. m.						
				11	Solar halo, 22°	5:19 p. m.	5:25 p. m.						
				12	Solar halo, 22°	12:30 p. m.	6:20 p. m.						
				12	Parhelion, 22°, right	4:11 p. m.	5:15 p. m.						
				12	Parhelion, 22°, left	4:11 p. m.	5:53 p. m.						
				12	Upper tangent arc	1:34 p. m.	6:20 p. m.						
				12	Lower tangent arc	4:11 p. m.	4:40 p. m.						
				12	Solar halo, 46°	4:45 p. m.	5:15 p. m.						
				12	Circumzenithal arc	4:45 p. m.	5:15 p. m.						
				13	Solar halo, 22°	1:25 p. m.	Sunset.						
				13	Parhelion, 22°, right	3:13 p. m.	Sunset.						
				13	Parhelion, 22°, left	3:13 p. m.	Sunset.						
				13	Upper tangent arc	3:13 p. m.	Sunset.						
				13	Circumscribed halo	1:43 p. m.	4:55 p. m.						
				13	Solar halo, 46°	4:03 p. m.	6:52 p. m.						
				13	Parhelion, 46°, right	5:40 p. m.	6:01 p. m.						
				13	Circumzenithal arc	5:29 p. m.	6:35 p. m.						
				13	Parhelic circle	4:30 p. m.	4:55 p. m.						
				13	Light pillar	6:27 p. m.	Sunset.						
				14	Solar halo, 22°	D. N. a.	3:45 a. m.						
				14	Parhelion, 22°, right	D. N. a.	3:40 a. m.						
				14	Parhelion, 22°, left	D. N. a.	3:45 a. m.						
				14	Light pillar	D. N. a.	4:03 a. m.						
				14	Solar halo, 22°	5:25 a. m.	9:20 a. m.						
				14	Parhelion, 22°, right	6:15 a. m.	8:55 a. m.						
				14	Parhelion, 22°, left	6:15 a. m.	8:50 a. m.						
				14	Lowitz arc, right	8:05 a. m.	8:50 a. m.						
				14	Lowitz arc, left	8:05 a. m.	8:50 a. m.						
				14	Upper tangent arc	5:32 a. m.	9:20 a. m.						
				14	Lower tangent arc	8:05 a. m.	8:50 a. m.						
				14	Solar halo, 46°	5:25 a. m.	8:50 a. m.						
				14	Parhelion, 46°, right	8:25 a. m.	8:35 a. m.						
				14	Parhelion, 46°, left	8:25 a. m.	8:35 a. m.						
				14	Circumzenithal arc	6:15 a. m.	7:20 a. m.						
				14	Parhelic circle	8:05 a. m.	9:10 a. m.						
				14	Paranthelion, 120°, right	8:20 a. m.	8:50 a. m.						
				14	Paranthelion, 120°, left	8:05 a. m.	8:50 a. m.						
				14	Anthelion	8:25 a. m.	8:35 a. m.						
				14	Light pillar	5:25 a. m.	5:42 a. m.						
				14	Secondary halo	8:25 a. m.	8:30 a. m.						
				15	Solar halo, 22°	3:48 p. m.	3:55 p. m.						
				16	Solar halo, 22°	7:55 a. m.	9:58 a. m.						
				20	Solar halo, 22°	6:37 a. m.	6:52 a. m.						
				20	Parhelion, 22°, right	6:56 a. m.	6:58 a. m.						
				20	Parhelion, 22°, left	6:49 a. m.	6:58 a. m.						
				20	Circumzenithal arc	6:37 a. m.	6:52 a. m.						
				20	Solar halo, 22°	11:44 a. m.	3:10 p. m.						
				20	Parhelion, 22°, left	4:55 p. m.	5:20 p. m.						
				21	Solar halo, 22°	5:30 p. m.	6:31 p. m.						
				22	Solar halo, 22°	4:17 p. m.	Sunset.						
				22	Parhelion, 22°, right	4:56 p. m.	Sunset.						
				22	Parhelion, 22°, left	5:38 a. m.	5:40 a. m.						
				22	Upper tangent arc	4:30 p. m.	5:10 p. m.						
				23	Solar halo, 22°	5:49 a. m.	7:18 p. m.						
				23	Parhelion, 22°, right	2:30 p. m.	4:20 p. m.						
				23	Parhelion, 22°, left	2:30 p. m.	4:20 p. m.						
				23	Upper tangent arc	6:30 p. m.	7:18 p. m.						
				23	Circumscribed halo	3:00 p. m.	4:15 p. m.						
				23	Solar halo, 46°	3:00 p. m.	6:40 p. m.						
				23	Light pillar	6:35 p. m.	7:05 p. m.						
				25	Solar halo, 22°	4:26 p. m.	4:40 p. m.						
				26	Parhelion, 22°, right	5:07 a. m.	5:15 a. m.						
				26	Parhelion, 22°, left	5:14 a. m.	5:15 a. m.						
				27	Solar halo, 22°	7:07 p. m.							
York, N. Y. †	232	42 52	77 53	14	Solar halo, 22°	12:40 p. m.		12:45 p. m.			360		
				15	Solar halo, 22°	12:30 p. m.	1:15 p. m.	12:45 p. m.			360		
				16	Solar halo, 22°	12:00 m.	12:45 p. m.	12:30 p. m.			300		
				19	Solar halo, 22°	12:15 p. m.	7:40 p. m.	6:30 p. m.			300		19
				19	Parhelion, 22°, right	6:15 p. m.		6:30 p. m.				22.5	
				19	Parhelion, 22°, left	6:25 p. m.		6:30 p. m.				22.5	
				19	Upper tangent arc		7:55 p. m.	6:30 p. m.			30	23	
				19	Solar halo, 46°	7:15 p. m.	8:02 p. m.	7:45 p. m.			180	46	6
				19	Circumzenithal arc		7:35 p. m.	6:30 p. m.			20	46	
				24	Solar halo, 22°	11:30 a. m.	1:00 p. m.	12:30 p. m.			360		
				24	Parhelion, 22°, left	7:20 p. m.	7:35 p. m.	7:30 p. m.					

* Aerological station.

† Same taken at Rochester, N. Y.

Halo phenomena observed during May, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness.	Clouds.			Station pressure.	Precipitation.	
				Amt.	Kind.	Direction.		Last previous ended.	First subsequent began.
Broken Arrow, Okla.*	14	Y	Dim	8	Ci. St.	nw.	Stationary	7:10 p. m., 12th	11:23 a. m., 16th.
	15	R	Bright	3	Ci.	w.	Stationary	7:10 p. m., 12th	11:23 a. m., 16th.
				5	Ci. St.	w.			
	15								
	15	R	Dim	5	Ci. St.	w.	Falling	7:10 p. m., 12th	11:23 a. m., 16th.
	15								
	16	R	Dim	1	Ci.	w.	Stationary	7:10 p. m., 12th	11:23 a. m., 16th.
				3	A. St.	w.			
	16								
	16								
	23	R. Y	Dim	4	Ci.	w.	Stationary	6:45 a. m., 23d	10:51 a. m., 23d.
				4	A. St.	sw.			
	24	W	Dim	9	Ci. St.	wsw.	Falling	3:45 p. m., 23d	1:04 p. m., 24th.
				Few.	A. Cu.	sw.			
	24	R. Y	Bright	2	Ci. St.	wsw.	Falling	1:19 p. m., 24th	2:48 p. m., 24th.
				7	Cu.	ese.			
	25	R	Dim	2	Ci. St.	w.	Stationary	6:28 a. m., 25th	9:34 a. m., 26th.
				6	Cu.	sw.			
Canton, N. Y.	1	R	Dim	3	Ci. St.	w.	Falling	D. N., a., 29th	11:42 a. m., 1st.
	3		Dim	1	A. St.	w.	Stationary	8:22 a. m., 2d	9:22 p. m., 3d.
				2	Ci. St.	w.			
	4	R	Dim	2	Ci. St.	w.	Falling	D. N., a., 4th	4:56 p. m., 4th.
	6	R	Dim	1	Ci. St.	w.	Falling	7:38 a. m., 5th	7:15 a. m., 7th.
	15	B	Dim	2	Ci. St.	w.	Falling	7:25 a. m., 12th	D. N., p., 15th.
	16		Dim					D. N., a., 16th	11:48 a. m., 16th.
	19	R	Dim	2	Ci.	w.	Stationary	4:04 p. m., 18th	6:52 p. m., 20th.
	20	R	Dim	1	Ci.	w.	Stationary	4:04 p. m., 18th	6:52 p. m., 20th.
				1	A. St.	w.			
	27	R	Dim				Rising	1:48 p. m., 25th	D. N., a., 6th.
	27	R	Dim	3	Ci. St.	w.		1:48 p. m., 25th	D. N., a., 6th.
Cincinnati, Ohio	3	R. O	Dim	1	Ci. St.	w.	Falling	7:30 p. m., 1st	D. N., a., 5th.
				8	A. St.	w.			
	19	R. Y. B	Dim	9	Ci. St.	sw.	Falling	D. N., p., 16th	5:09 p. m., 19th.
	26	R. O. Y. G	Bright	2	Ci. St.	nw.	Falling	6:43 a. m., 24th	
	26	R. O. Y. G	Bright	2	Ci. St.	nw.	Falling	6:43 a. m., 24th	
Dayton, Ohio	3	R	Dim	1	Ci.	w.	Falling	5:30 p. m., 1st	D. N., a., 5th.
				6	St.	w.			
	15	R	Dim	5	Ci. St.	w.	Stationary	D. N., a., 15th	10:07 a. m., 16th.
	18		Dim	6	Ci. St.	w.	Falling	7:10 p. m., 16th	6:20 p. m., 19th.
	19		Dim	7	Ci. St.	w.	Falling	7:10 p. m., 16th	6:20 p. m., 19th.
Drexel, Nebr.*	4	O. W	Bright	9	Ci. St.	w.	Rising	6:06 a. m., 4th	D. N., a., 6th.
				Few.	A. Cu.	w.			
	7	R. O. W	Dim	6	Ci. St.	sw.	Rising	11:00 a. m., 6th	4:30 a. m., 11th.
				Few.	A. St.	sw.			
	7	O. G	Dim	4	Ci. St.	sw.	Stationary	11:00 a. m., 6th	4:30 a. m., 11th.
				Few.	A. Cu.	sw.			
	10	O. Y. G	Brilliant	7	Ci. St.	sw.	Falling	11:00 a. m., 6th	4:30 a. m., 11th.
				1	Cu.	s.			
	10	O. Y. G	Brilliant	7	Ci. St.	sw.			
				1	Cu.	s.			
	23	O. Y. B	Brilliant	6	Ci. St.	nw.	Stationary	2:45 p. m., 19th	8:20 a. m., 26th.
				Few.	Cu.	nw.			
Ellendale, N. Dak.*	17	Y. B	Dim	7	Ci. St.	w.	Falling	3:55 p. m., 15th	D. N., p., 17th.
	20	R. O. Y. G	Bright	6	Ci. St.	nw.	Falling	7:45 p. m., 18th	12:40 p. m., 30th.
Groesbeck, Tex.*	3	R. O. Y. G. B	Bright	4	Ci. St.	w.	Falling	D. N., p., 29th	9:10 p. m., 5th.
				3	Cu.	sw.			
	11						Rising	4:17 p. m., 11th	6:25 p. m., 14th.
	11	R. O. Y. G. B	Bright				Rising	4:17 p. m., 11th	6:25 p. m., 14th.
	12	R. O. Y. G. B	Bright	6	Ci. St.	w.	Rising	4:17 p. m., 11th	6:25 p. m., 14th.
	12	R. O. Y. G. B	Bright	1	St.	w.			
	12	R. O. Y. G. B. I	Bright						
	12	R. O. Y	Dim						
	12	R. O. Y. G. B	Dim						
	13						Rising	4:17 p. m., 11th	6:25 p. m., 14th.
	17	R. O. Y. G. B. V	Brilliant	6	Ci. St.	w.	Stationary	D. N., a., 17th	8:37 a. m., 19th.
				1	Cu.	w.			
Leesburg, Ga.*	1	R. Y	Dim	1	Ci. Cu.	ssw.	Stationary	9:15 a. m., 1st	1:46 p. m., 1st.
				1	Ci. St.	sw.			
	4	R	Dim	5	Ci.	w.	Stationary	5:55 p. m., 1st	5:45 a. m., 5th.
				2	Ci. St.	w.			
	4			9	Ci. St.	w.	Rising	5:55 p. m., 1st	5:45 a. m., 5th.
	8	R. O. Y. G	Bright	5	Ci. St.	s.	Falling	4:20 p. m., 7th	10:45 a. m., 9th.
				5	Cu.	sse.			
	8	R	Dim	7	Ci. St.	s.	Stationary	4:20 p. m., 7th	10:45 a. m., 9th.
	9	R	Dim	7	A. St.	w.	Stationary	11:50 a. m., 9th	10:23 a. m., 10th.
				2	St. Cu.	w.			
	12	R. Y	Dim	4	Ci. St.	w.	Stationary	10:30 a. m., 10th	11:38 a. m., 13th.
				2	Cu.				
	13	R	Dim	4	Ci. St.	w.	Falling	11:43 a. m., 13th	3:44 p. m., 13th.
				2	St. Cu.	w.			
	16	R	Dim	6	Ci. St.	nw.	Stationary	D. N., a., 14th	10:09 a. m., 19th.
				2	Cu.	w.			
	16	R. Y. G	Dim						
	16	R. Y. G	Dim						
	16	R	Dim	6	Ci. St.	nw.	Stationary	D. N., a., 14th	10:09 a. m., 19th.
				1	Cu.	w.			
	18	R. Y	Dim	4	Ci. St.	w.	Stationary	D. N., a., 14th	10:09 a. m., 19th.
				Few.	Cu.				
	19	R	Dim	5	Ci. St.	w.	Stationary	D. N., a., 14th	10:09 a. m., 19th.
				4	A. Cu.	w.			
	19	R. Y. G	Bright						
	19	R. Y. G	Bright						
	20	R. G. Y	Bright	2	Ci. St.	w.	Stationary	D. N., p., 19th	9:10 a. m., 20th.
				2	A. Cu.	sw.			
	24			9	Ci. St.	w.	Stationary	9:45 p. m., 21st	12:58 p. m., 25th.
	26	R. Y. G	Bright	7	Ci. St.	sw.	Stationary	5:17 p. m., 25th	2:23 p. m., 26th.
				1	A. Cu.	wsw.			
	27	R. Y	Dim	8	Ci. St.	w.	Falling	5:00 p. m., 26th	1:43 p. m., 27th.
				2	A. Cu.	sw.			
	28	R. Y	Dim	1	A. Cu.	sw.	Stationary	D. N., a., 28th	D. N., a., 29th.
				9	A. St.	ssw.			

* Aerological station.

† Beginning with part nearest sun or moon, R. red; O. orange; etc.

Halo phenomena observed during May, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness.	Clouds. Amt.	Clouds. Kind.	Clouds. Direction.	Station pressure.	Precipitation. Last previous ended.	Precipitation. First subsequent began.
Leesburg, Ga.* (continued)	28	R. O	Bright	4	A. Cu.	sw.	Stationary	D. N., a., 28th	D. N., a., 29th.
				6	A. St.	sw.			
	29	R. O. G	Dim	2	A. Cu.	se.	Falling	D. N., a., 29th	1:06 p. m., 29th.
				3	A. St.	se.			
Madison, Wis	2	R	Bright	10	Ci. St.	sw.	Rising	5:30 p. m., 1st	D. N., a., 3d.
	5	R	Bright	10	Ci. St.	w.	Falling	1:15 p. m., 4th	6:40 a. m., 6th.
	5	R	Bright						
	8	R	Bright	5	Ci. St.	sw.	Stationary	D. N., p., 6th	11:00 a. m., 14th.
	8		Dim				Stationary	D. N., p., 6th	11:00 a. m., 14th.
	9						Rising	D. N., p., 6th	11:00 a. m., 14th.
	9								
	12	R	Brilliant	10	Ci. St.	w.	Rising	D. N., p., 6th	11:00 a. m., 14th.
	12								
	12								
	12		Bright	10	Ci. St.	w.			
	12			3	Ci. St.	n. w.	Rising	8:00 p. m., 16th	8:30 a. m., 20th.
	17		Bright						
	17								
	18	R	Brilliant	10	Ci. St.	n. w.	Falling	8:00 p. m., 16th	8:30 a. m., 20th.
	19		Bright	10	Ci. St.	w.	Stationary	8:00 p. m., 16th	8:30 a. m., 20th.
	19								
	20						Rising	8:00 p. m., 16th	8:30 a. m., 20th.
	23		Bright	5	Ci. St.	nw.	Rising	D. N. a., 23rd	9:45 p. m., 30th.
				5	A. St.	nw.			
	27		Dim	10	Ci. St.	w.	Stationary	D. N. a., 23rd	9:45 p. m., 30th.
	31		Bright	4	Ci. St.	nw.	Falling	10:20 p. m., 30th	6:30 p. m., 31st.
				6	St. Cu.	se.			
Nashville, Tenn	4	O. Y	Bright	4	Ci.	w.	Stationary	D. N. a., 1st	2:10 p. m., 5th.
	12	R. O. Y	Dim	8	Ci. St.	sw.	Falling	7:30 p. m., 10th	3:05 p. m., 12th.
	13	R. O	Dim	5	Ci.	sw.	Stationary	3:07 p. m., 12th	3:42 p. m., 16th.
	19	R. O. Y	Bright	10	Ci. St.	w.	Falling	5:30 a. m., 17th	2:10 p. m., 19th.
	26	O	Dim	10	A. St.	w.	Falling	2:20 p. m., 26th	6:40 p. m., 26th.
Royal Center, Ind.*	12	R	Dim	7	Ci. St.	w.	Falling	D. N. p., 8th	D. N. a., 16th.
	12	R. O. Y. G. B	Bright	8	Ci. St.	w.	Falling	D. N. p., 8th	D. N. a., 16th.
				1	Cu.	n.			
	26	R	Dim	6	Ci. St.	nw.	Falling	D. N. p., 23rd	4:24 p. m., 2nd.
	26	R	Dim	4	Ci. St.	nw.			
Tatoosh Island, Wash	1	W	Dim	1	Ci. St.	w.	Rising	8:40 a. m., 1st	3:43 p. m., 8th.
				6	St. Cu.	w.			
	1	R. O. B. W	Bright						
	1	R. O. Y. B. W	Bright	Few	Ci. St.	w.			
				7	St. Cu.	w.			
	8	R. O. Y. G. B. V	Bright	1	A. St.	sw.	Rising	8:40 a. m., 1st	3:43 p. m., 8th.
				9	St.	sw.			
	9	O	Dim	6	Ci. St.	sw.	Rising	D. N. p., 8th	7:00 a. m., 9th.
				3	St.	wnw.			
	9	R. B	Dim	1	A. St.	sw.			
				9	St.	wnw.			
	10	O	Dim	9	A. St.	w.	Rising	7:40 a. m., 9th	D. N. p., 10th.
				1	Cu.	w.			
	11	W	Dim	1	A. St.	sw.	Falling	5:10 p. m., 11th	7:05 p. m., 11th.
				8	Cu.	sw.			
	12	R. O. B. V	Bright	Few	Ci. St.	w.	Rising	9:10 a. m., 12th	1:25 p. m., 14th.
				2	Cu.	w.			
	12	R. Y. B. V. W	Bright	6	Ci. St.				
				2	Cu.	sw.			
	12	R. Y. G. B. V. W	Bright						
	12	R. O. Y. B	Bright	3	Ci. St.				
				6	Cu.	sw.			
	12	Y	Dim						
	12	R. O. B	Dim	7	Ci. St.				
				2	Cu.	sw.			
	12	R. O. B	Dim						
	13	R. O. Y. G. B. V	Brilliant	9	A. St.	s.	Falling	3:30 p. m., 12th	1:25 p. m., 14th.
	13	R. O. Y. G. B. V. W	Bright	9	A. St.	s.			
	13	R. O. Y. G. B. V. W	Bright						
	13	R. O. Y. G. B. V	Bright						
	13	Y	Dim	10	A. St.	s.			
	13	R. O. G. B. V	Bright	9	Ci. St.				
				1	Ci. Cu.	sw.			
	13	W	Dim	8	Ci. St.	s.			
				1	A. St.	s.			
	13	R. O. G. B. V	Bright	8	Ci. St.	s.			
				1	A. St.	s.			
	13	W	Dim						
	13	Y	Bright	9	Ci. St.	s.			
	14	O	Dim	4	Ci. St.		Falling	3:30 p. m., 12th	1:25 p. m., 14th.
				6	A. St.	s.			
	14	O. W	Dim						
	14	O. W	Dim						
	14	Y	Dim						
	14	R. O. Y. G. B. V	Brilliant	3	Ci. St.	s.	Falling	3:30 p. m., 12th	1:25 p. m., 14th.
				6	A. St.	s.			
	14	R. O. Y. G. B. V. W	Brilliant	3	Ci. St.	s.			
				6	A. St.	s.			
	14	R. O. Y. G. B. V. W	Brilliant						
	14	R. O. Y. G. B. V	Bright						
	14	R. O. Y. G. B. V	Bright						
	14	R. O. Y. G. B. V	Brilliant						
	14								
	14	R. O. Y. G. B. V	Brilliant						
	14	W	Dim	9	Ci. St.	s.			
	14	W	Dim						
	14	R. O. B	Dim						
	14	W	Bright	9	Ci. St.	s.			
	14	W	Bright						
	14	W	Bright						
	14	W	Bright						
*	14	Y	Dim						
	14								

* Aerological station.

† Beginning with part nearest sun or moon. R. red; O. orange; etc.

Halo phenomena observed during May, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness.	Clouds. Amt.	Clouds. Kind.	Clouds. Direction.	Station pressure.	Precipitation. Last previous ended.	Precipitation. First subsequent began.
Tatoosh Island, Wash. (continued)	15	W	Dim	6	A. St.	s.	Falling	1:55 p. m., 15th.	4:40 p. m., 15th.
				2	Cu.	s.			
	16	O	Dim	7	A. St.	s.	Falling	7:40 a. m., 16th.	7:40 a. m., 17th.
				2	St.	s.			
	20		Dim	3	Ci. St.	s.	Falling	8:30 a. m., 19th.	D. N. a., 22d.
				1	Ci. Cu.	w.			
	20	R. O. Y. G. B. V. W.	Bright	4	Ci. St.	s.			
	20	R. O. Y. G. B. V. W.	Brilliant	4	Ci. St.	s.			
	20	R. Y. B	Brilliant						
	20	R. O. Y. B	Bright	3	Ci.	w.	Falling	8:30 a. m., 19th.	D. N. a., 22nd.
	20	W	Dim	2	Ci.	w.			
	21		Dim	2	Ci.	sw.	Falling	8:30 a. m., 19th.	D. N. a., 22nd.
	22	R. O. Y. G. B. V.	Bright	4	A. St.	w.	Rising	D. N. a., 22nd.	3:40 a. m., 24th.
				5	St.	nw.			
	22	R. V. W	Dim	5	Ci. St.	w.			
				2	St.	nw.			
	22	R. O. G. V	Brilliant	Few.	A. St.	sw.			
				6	St.	sw.			
	22	Y	Dim	4	A. St.	w.			
				4	St.	nw.			
	23	R. O. Y. G. B. V.	Bright	3	Ci.	w.	Rising	D. N. a., 22nd.	3:40 a. m., 24th.
				1	St. Cu.	w.			
	23	R. O. Y. G. B. V. W.	Bright	8	Ci. St.	sw.			
	23	R. O. Y. G. B. V. W.	Bright						
	23	Y	Dim						
	23	Y	Dim						
	23	R. B	Dim	7	Ci. St.	sw.			
	23	Y	Dim	10	A. St.				
	25		Dim	7	Ci. St.	s.	Rising	3:25 p. m., 25th.	5:50 a. m., 26th.
				3	St.	sw.			
	26	R. Y. B	Bright	Few.	Ci. St.	sw.	Rising	3:25 p. m., 25th.	5:50 a. m., 26th.
				4	A. Cu.	sw.			
	26	R. B	Bright	Few.	Ci. St.	sw.			
				4	A. Cu.	sw.			
	27		Dim	Few.	Ci. St.	s.	Falling	4:30 a. m., 27th.	D. N. p., 28th.
				Few.	Cu.				
York, N. Y.*	14	Y. W	Dim	9	Ci. St.	w.	Falling	12:10 p. m., 12th.	2 p. m., 15th.
	15	R. O. Y. W	Brilliant	9	Ci. St.	w.	Stationary	12:10 p. m., 12th.	2 p. m., 15th.
	16	Y. W	Bright	5	Ci. St.	w.	Falling	3:40 p. m., 15th.	2 p. m., 16th.
				5	St. Cu.	sw.			
	19	O. Y. W	Bright	9	Ci. St.	w.	Stationary	9:30 a. m., 17th.	6:30 a. m., 20th.
	19	R. Y. W	Bright						
	19	Y. W	Dim						
	19	R. O. Y. W	Brilliant						
	19	R. O. G	Bright	10	Ci. St.	w.			
	19	R. G	Dim						
	24	O. Y. W	Bright	4	Ci. St.	w.	Stationary	4 p. m., 23rd.	3:40 p. m., 24th.
				2	A. St.	w.			
	24	O							

* Same taken at Rochester, N. Y. † Beginning with part nearest sun or moon. R. red; O. orange; etc.

NOTES.

HALOS, TATOOSH ISLAND, WASH., MAY 12–14, 1919.

Unusually well-defined halos and attendant phenomena were observed here on the 12th, 13th, and 14th. Figure 1 shows the unusual variety of forms observed at 8:25 a. m. on the 14th.—*R. C. Mize.*

PARHELIC CIRCLE AND HALOS OBSERVED AT LANSING, MICH., MAY 19, 1919.

A partial ordinary 22° halo, first noticed at 9:15 a. m. (90th mer. time), May 19, 1919, was kept under observation, and was noted as becoming complete and bright between 10:15 and 10:30. Then elliptical bulging of the sides indicated the formation of the circumscribed arc, which became well-defined at about 10:50, its presence being proved by the extra series of prismatic colors visible on the bulged sides of the ordinary halo.

At this time another arc appeared, this one quite capable of misleading the observer. It was a circle of whitish color, apparently of the same size as the 22° halo, and overlapping this on the side toward the zenith, in such a manner that the center of each of the two circles seemed to be located on the circumference of the other: it gave the impression of a reflected 22° halo whose edge passed through the sun. Coincidence, however, accounted for the similar size of the two rings, for the whitish upper circle was the complete parhelic circle with the sun at altitude 66° 7′, indicating that its radius was about a degree larger than that of the halo. This measurement was made at 11:00, when it was best in definition, but faint in comparison to the brilliant 22° halos. Its white circumference was studied in vain for a glimpse of "knots" or parhelia. A measurement of the radius of the ordinary halo was made at 11:00: the result being 21.7° from the center of the sun to the red of the ring at this solar altitude (66.7°).

The rapid fading of the parhelic circle and its disappearance by 11:10, while no change in cloud structure or halo brightness was visible, leads to the supposition that the parhelic circle reached the limit for its formation when the sun's altitude approached 68°, when the arc would have been of about 22° radius.

Thickening cirrus forms and altostratus types of cloud blurred and finally eclipsed the ordinary halo, but at intervals until 3:40 p. m. it was observed as partially formed.

Measurements were made by theodolite.—*C. G. Andrus.*

BRILLIANT SOLAR HALO AT KINGSTON, JAMAICA, MAY 24, 1919.

On the morning of the 24th of May at about 9 a. m. there appeared a very fine, brilliant and complete solar halo over Kingston. The prismatic colors from red to green, were distinct, but I could not discern any blue; the light there merged into white. I took 23 angular measurements (in a vertical plane) across the diameter

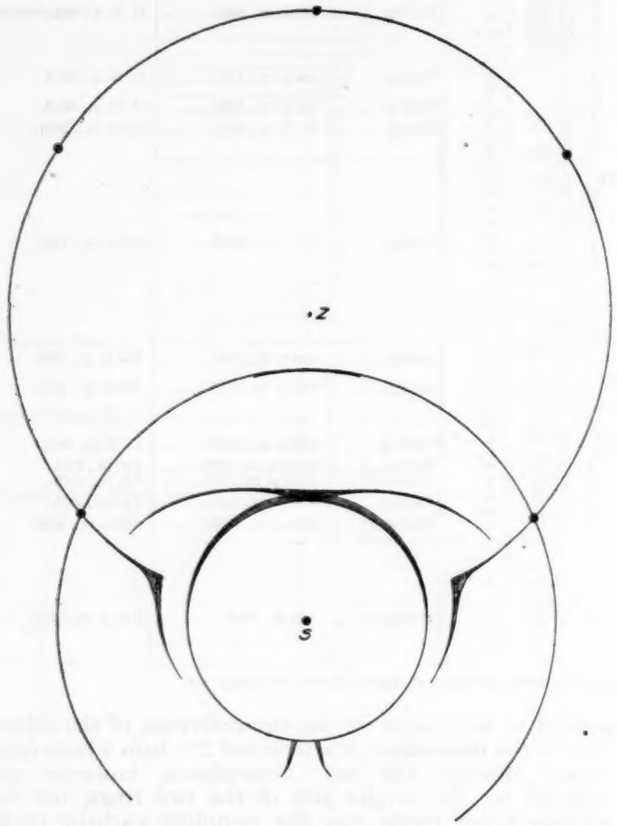

FIG. 1.—Solar halo phenomena, 8:25 a. m., May 14, 1919, Tatoosh Island, Wash., observed by R. C. Mize.

of the complete ring from centers of red to red, from about 10 a. m. and derived a mean radius of 22° 26′. The sun's altitude was then about 70°. I have not allowed for atmospheric refraction, for the lower edge of the ring, being of altitude of about some 50°, would be affected by barely 1′ of arc. There were then very thin cirrus stripes and cirro-stratus with a trace of cirro-cumulus from a west-southwesterly direction. The moon in the southwest was fairly visible through the veil of cirrus. I may state that within the area of the ring the clouds appeared mottled, and resembled altogether, cirro-cumulus, but this must have been owing to the intensity of light. The central area was considerably darker than the outside. Immediately exterior to the ring the cirrus stripes began to be clearly visible. There was also passing some lower cloud (fracto-cumulus) with an easterly direction. The barometer was normal; temperature of air 87° at 10 a. m.; humidity 64 per cent; wind southeast 15 miles. There was also a secondary concentric ring, but a sector near the horizon of only about 45° arc. I took four angular measures of this from the sun and obtained a mean result of 47° 4′ radius; the lower edge was 22° above the horizon; the correction for atmospheric refraction would be only about 2′. The halo almost completely disappeared about 1 p. m., lasting about four hours. I noted near 1 p. m. that the

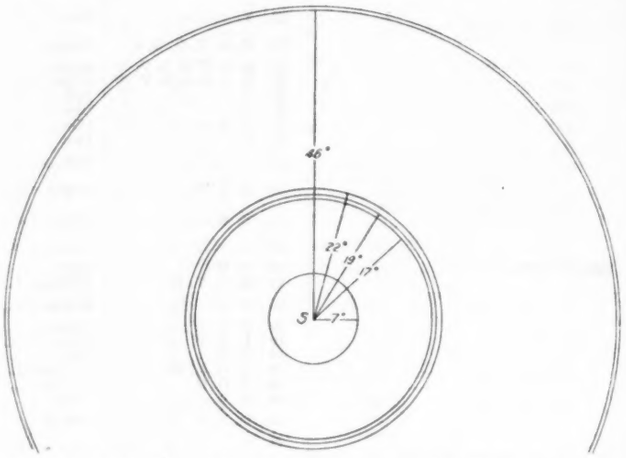

FIG. 2.—Quintuple solar halos observed at 1:35 p. m., May 26, 1919, by J. W. Brush.

fading away of the halo appeared on the cirrus stripes only, there was then some feathery cirrus, but the halo did not show up as these latter developed.—*J. F. Brennan.*

QUINTUPLE SOLAR HALOS.

Four colored halos and one white one were observed at 1:35 p. m., May 26, 1919. (See fig. 2.) They were of about 7°, 17°, 19°, and 22°, and 46° radius. All four smaller ones were colored bright enough to see real plain; the 46°-halo, in double lines, was white and dim. I have never seen more than 2 complete and 2 short arcs at once before. I got their size as best I could with crude construction of my own, then with compass and stand I made an illustration on the place of observation.—*Judson W. Brush.*

SOLAR AND SKY RADIATION MEASUREMENTS DURING MAY, 1919.

By HERBERT H. KIMBALL, Professor of Meteorology, in Charge.

[Dated: Solar Radiation Investigations Section, Washington, June 30, 1919.]

For a description of instrumental exposures and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, 47:4.

The monthly means and departures from normal in Table 1 show that the radiation measurements averaged slightly below the May normal at Washington and Santa Fe, and slightly above at Madison and Lincoln. Unusually hazy conditions prevailed at Washington after May 23, and at Madison and Lincoln, after May 29, and continued into June. At Washington the haze at times closely resembled cirrus haze, and was, in fact, recorded by one observer as 10 Ci. St. At Madison Mr. E. R. Miller identified it as the usual summer water-haze, which is in accord with my own observations.

Table 3 shows a deficiency of 12 per cent in the total radiation for the month at Washington as compared with the normal amount for May, while Madison and Lincoln show excesses of 2 per cent and 5 per cent, respectively.

The skylight polarization at Washington on May 3 was 58 per cent, and on May 22, 51 per cent. On June 4 it was only 31 per cent. At Madison, measurements made on four days give a mean of 60 per cent, with a maximum of 67 per cent on the 2d. On the 29th the polarization was only 38 per cent.

TABLE 1.—*Solar radiation intensities during May, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
May 2	1.41					0.82	0.75			
3	1.37	1.23	1.10	1.02	0.95	0.88	0.80	0.75	0.72	0.68
5		1.14								
13			1.18	1.06						
22	1.29	1.19	1.00	0.88						
23							0.65			
27			0.78	0.66						
28	0.75	0.62	0.51	0.46						
29	0.99									
31		0.60								
Monthly means	**1.16**	**0.96**	**0.91**	**0.82**	**(0.95)**	**(0.85)**	**0.73**	**(0.75)**	**(0.72)**	**(0.68)**
Departure from 11-year normal	**−0.12**	**−0.14**	**−0.05**	**−0.06**	**+0.16**	**+0.11**	**+0.02**	**+0.15**	**+0.15**	**+0.17**
P. M.										
May 2		1.27	1.14	1.02						
3		1.18	0.97	0.87	0.73	0.60	0.50			
29		0.72								
Monthly means		**1.06**	**(1.06)**	**(0.94)**	**(0.73)**	**(0.60)**	**(0.50)**			
Departure from 11-year normal		**−0.06**	**+0.08**	**+0.09**	**−0.05**	**−0.12**	**−0.20**			

Madison, Wis.

A. M.										
May 2			1.34	1.27	1.19	1.11	1.03			
7							1.13			
10	1.47	1.38	1.28	1.20		1.03	0.96	0.91	0.85	
17	1.46	1.37	1.30	1.20	1.13	1.07				
29	1.20	1.02	0.88							
Monthly means	**1.38**	**1.26**	**1.20**	**1.22**	**(1.16)**	**1.07**	**1.04**	**(0.91)**	**(0.85)**	
Departure from 9-year normal	**+0.04**	**+0.04**	**+0.10**	**+0.20**	**+0.20**	**+0.10**		**+0.03**		

TABLE 1.—*Solar radiation intensities during May, 1919*—Continued.

Madison, Wis.—Continued.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
P. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
May 9		1.30	1.15	1.02	0.90	0.79				
10		1.30	1.16	1.07	0.95	0.84				
17		1.33								
Monthly means		**1.31**	**(1.16)**	**(1.04)**	**(0.92)**	**(0.82)**				
Departure from 9-year normal		**+0.07**	**+0.14**	**+0.06**	**−0.02**					

Lincoln, Nebr.

A. M.										
May 1		1.29	1.22	1.12	1.03	0.95	0.87	0.80	0.74	
3		1.22								
8	1.41	1.27	1.20	1.03	0.97	0.86				
14		1.34	1.28	1.15	1.01	0.87				
15	1.41	1.25	1.01	0.80						
20		1.21								
21		1.27	1.14	1.03	0.93	0.83				
22		1.10	1.01	0.89						
24		1.18	1.04	0.95						
30					0.80					
31					0.88					
Monthly means	**(1.41)**	**1.24**	**1.13**	**1.00**	**0.94**	**0.88**	**(0.87)**	**(0.80)**	**(0.74)**	
Departure from 4-year normal	**+0.06**	**−0.02**	**−0.02**	**−0.03**	**+0.03**	**±0.00**	**+0.05**	**+0.02**	**−0.06**	
P. M.										
May 1		1.34	1.24	1.13	1.09	1.01	0.94	0.88	0.82	0.77
6		1.35	1.29	1.21	1.14	1.07	1.02	0.96	0.91	
8		1.35	1.20	1.07	0.96	0.86	0.77			0.66
15		1.25	1.10	0.99	0.91	0.83	0.76	0.69	0.63	
29			0.91	0.82	0.72	0.57	0.46		0.37	
Monthly means		**1.32**	**1.15**	**1.04**	**0.96**	**0.87**	**0.79**	**0.84**	**0.68**	**(0.72)**
Departure from 4-year normal		**+0.12**	**+0.10**	**+0.08**	**+0.09**	**+0.08**	**+0.06**	**+0.04**	**−0.01**	

Santa Fe, N. Mex.

A. M.										
May 1		1.45			1.07	1.02				
6		1.44	1.37	1.29		1.14				
8		1.41	1.31	1.25	1.17	1.10	1.07	0.97		
12	1.53									
17	1.41	1.29	1.19	1.10	1.02	0.96	0.90	0.83		
20	1.43									
21		1.37								
27		1.29	1.24	1.17		1.03				
31			1.20							
Monthly means	**1.46**	**1.38**	**1.26**	**1.20**	**1.09**	**1.05**	**(0.98)**	**(0.90)**		
Departure from 7-year normal	**−0.05**	**−0.01**	**−0.02**	**−0.02**	**−0.07**	**−0.06**	**−0.08**	**−0.11**		
P. M.										
May 12		1.30								
Monthly mean		**(1.30)**								
Departure from 3-year normal		**+0.10**								

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.
1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*
May 2	10.21	7.29	May 2	4.57	3.81	May 1	6.50	4.57	May 1	5.36	4.17
3	7.29	7.29	7	5.36	5.56	3	10.59	9.14	6	4.57	3.81
5	12.24	14.60	9	4.75	4.75	6	11.38	6.27	8	5.16	3.81
13	7.29	8.48	10	4.57	4.75	8	7.04	5.79	12	4.95	4.37
22	12.68	9.83	17	5.16	4.57	14	7.04	9.47	17	6.76	4.75
23	9.47	10.21	29	8.48	9.47	15	10.59	6.27	20	5.79	6.76
27	11.38	13.61				20	6.27	5.16	21	6.76	6.76
28	9.83	12.68				21	7.04	6.76	27	6.50	7.04
29	13.61	15.11				22	7.04	6.50	31	5.56	6.02
31	9.83	12.24				24	9.47	10.59			
						29	11.81	11.81			
						30	11.81	13.61			
						31	15.65	15.65			

TABLE 3.—*Daily totals and departures of solar and sky radiation during May, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
1	69	120	681	−391	−329	225	−391	−329	225
2	661	613	210	197	162	−250	−194	−167	−25
3	671	88	567	204	−365	103	10	−532	78
4	558	198	627	88	−257	158	98	−789	236
5	474	290	355	0	−167	−118	98	−956	118
6	186	140	452	−290	−318	−25	−192	−1,274	93
7	285	695	546	−192	235	64	−384	−1,039	157
8	105	431	747	−374	−30	261	−758	−1,069	418
9	195	681	530	−285	219	39	−1,043	−850	457
10	87	728	505	−395	265	10	−1,438	−585	467
11	211	644	186	−272	180	−313	−1,710	−405	154
12	422	567	130	−63	102	−373	−1,773	−303	−219
13	661	679	441	175	213	−66	−1,598	−90	−285
14	308	414	656	−180	−53	145	−1,778	−143	−140
15	527	273	745	38	−195	230	−1,740	−338	90
16	167	372	622	−323	−96	106	−2,063	−434	196
17	213	727	491	−278	258	−26	−2,341	−176	170
18	703	593	443	211	124	−74	−2,130	−52	96
19	656	569	672	164	100	155	−1,966	48	251
20	227	305	678	−266	−164	161	−2,232	−116	412
Decade departure							**−794**	**469**	**−55**
21	230	74	709	−264	−396	192	−2,496	−512	604
22	582	313	655	88	−157	148	−2,408	−669	752
23	405	450	643	−90	−20	126	−2,498	−689	878
24	352	602	630	−144	131	113	−2,642	−558	991
25	620	652	567	124	181	49	−2,518	−377	1,040
26	630	604	403	134	132	−118	−2,384	−245	922
27	637	621	252	141	147	−272	−2,243	−98	650
28	599	630	684	103	155	157	−2,140	57	807
29	644	626	686	148	149	156	−1,992	206	963
30	609	551	602	113	72	69	−1,879	278	1,032
31	554	522	292	58	41	−245	−1,821	319	787
Decade departure							**+411**	**+435**	**+375**
Excess or deficiency since first of year.	gr.-cal						**−2,360**	**−4,083**	**−2,588**
	per cent						**− 4.8**	**− 8.4**	**− 4.7**

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE, APRIL, 1919.

By Dr. C. G. ABBOT.

[Dated Astrophysical Observatory, Smithsonian Institution, Washington, June 17, 1919.]

I communicate the following results of the measurements of the solar constant of radiation which were made by the Smithsonian observers, Messrs. A. F. Moore and L. H. Abbot, at Calama, Chile, in the month of April, 1919.

The arrangement of the observations in the table is the same as that employed in the preceding REVIEWS.

TABLE 1.—*Solar-radiation observations at Calama, Chile, April, 1919.*

Date.	Solar const.	Grade.	Transmission coefficient at 0.5 microns.	Humidity air mass 3.			Remarks.
				p/p_{sa}	V. P.	Rel. hum.	
A. M.	*cal.*				*cm.*	%	
Apr. 1	1.960	E−	0.846	0.366	0.56	56	
2	1.946	E−	.853	.408	.41	40	
3	1.960	VG+	.828	.340	.57	65	
4	1.973	E−	.818	.299	.61	64	
5	1.938	VG	.852	.375	.53	55	
6	1.933	VG+	.854	.413	.38	36	
7	1.940	VG+	.852	.459	.35	37	
8	1.962	E−	.852	.495	.31	32	
9	1.947	VG	.864	.583	.24	23	
10	1.922	E−	.872	.621	.21	22	
11	1.925	E	.873	.588	.19	21	Cirri in west and south.
12	1.898	VG	.867	.432	.32	34	
13	1.928	E−	.868	.429	.36	37	Cloudless, except small patches of cirri in west and south.
14	1.984	VG+	.850	.440	.41	42	Cirri in distant south.
15	1.950	E−	.868	.525	.29	27	Cirri in north and east just below sun.
16	1.967	G+	.861	.525	.20	24	Cirri in north and east, moving rapidly south.
18	1.994	VG	.846	.441	.32	34	Some cirri in southeast.
19	1.970	VG+	.848	.418	.31	32	Some cirri.
22	2.004	G+	.853	.343	.55	64	Cumuli and cirri scattered about sky.
P. M.							
Apr. 23	1.920	VG+	.874	.571	.36	20	Cirri in north and east.
A. M.							
Apr. 24	1.900	E	.885	.591	.16	19	
25	1.930	E−	.877	.562	.19	22	Small patch of cirrus in west.
26	1.932	E−	.871	.549	.23	21	
27	1.953	E−	.868	.552	.19	19	
28	1.969	E−	.871	.608	.16	20	
29	1.946	E	.867	.569	.15	18	
30	1.943	E	.873	.589	.15	21	

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY, Meteorologist.

The annual reversal in normal pressure in the Northern Hemisphere is almost accomplished by the close of May. The great Asiatic high of winter has now disappeared and the normal pressure is highest over the Atlantic southwest of the Azores. Normal pressure is also high over the Pacific northeast of the Hawaiian group although the principal high is over the Atlantic, as above stated. Normal pressure is now least in equatorial regions, the principal depression being over British India with values as low as 29.60 inches. Normally there is an increase in pressure from April to May in both the Iceland and Aleutian regions of low pressure, hence both these regions are no longer to be considered as being under cyclonic control.

As far as can be determined at this writing the weather in the Northern Hemisphere for May, 1919, did not depart in any important respect from the normal for the season. The greatest abnormality observed was that of the prevailingly low pressure in Alaska and other northern regions when the normal change is toward rising pressure.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

Pressure was almost continuously, and at times markedly, below normal in the region of the Aleutian Islands until the closing days of the month. On the other hand, at Midway Island it was above normal except from the 8th to the 13th. Along the northern trans-Pacific steamer routes this pressure distribution resulted in the prevalence of westerly winds in midocean which at times attained gale force. Otherwise the weather of the month appears to have been without special features.

NORTH AMERICA.

By A. J. HENRY.

May, 1919, was lacking in positive characteristics, cyclonic and anticyclonic movement was sluggish and featureless. On the whole, it was a month of more than the average rainfall east of the Mississippi and in the West Gulf drainage. The abundant rainfall east of the Mississippi was associated with temperature below normal except locally in small areas. West of the Rocky Mountains unusually high temperatures prevailed.

So far as known, the month was devoid of destructive local windstorms and tornadoes.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

According to reports received from land stations on the American coast, the Azores, Bermuda, and the British Isles, the mean pressure for the month over the North Atlantic did not differ materially from the normal, although not enough vessel reports were received in time to determine the conditions accurately.

In an article by Mr. Willis Ray Gregg on "The First Trans-Atlantic Flight," that appears in this number of the REVIEW (p. 279–292), the weather conditions from May 12–20 and from the 27th to the 31st (both inclusive), are discussed, the article being accompanied by a series of charts showing the pressure distribution and direction and force of wind over the ocean for each day in both periods.

On May 1 a well-developed LOW was central near Sydney, Cape Breton Island, and moderate westerly gales were encountered between the center and the 40th parallel; during the next 24 hours the barometer rose rapidly at Sydney, and the LOW apparently moved northward, as on the 2d it did not appear within the limits of the chart, while the winds over the storm area of the 1st had decreased considerably in force. On the 3d the weather was moderate as a whole, with the exception of a limited area in midocean, where winds of from 40 to 45 miles an hour were reported, while fog covered the greater part of the Banks of Newfoundland.

From the 4th to the 8th, moderate winds were the rule, except that on the latter date, the observatory at Horta, Azores, recorded a southwesterly wind of 40 miles an hour, while at the same time snow occurred at St. Johns, N. F.

On the 9th there was a well-developed LOW central near latitude 46°, longitude 35°, and strong southerly gales prevailed in the easterly quadrants, while westerly winds of slightly less force were encountered a short distance west of the center.

The observer on the British Steamship *Malancha* stated in the storm log: "The gale began on the 9th, lowest barometer 28.57 inches at 4 p. m. on the 9th, latitude 48°–36′N, longitude 32°–58′W. End of gale on the 12th; highest force of wind 70 miles an hour; shifts of wind near time of lowest barometer, south to south-southwest to west to north-northwest."

The U. S. S. *Huntington* was some distance southwest of the center on the morning of the 9th, and an extract from the storm log is as follows: "Gale began on the 8th; lowest barometer 29.15 inches at 4 a. m. of the 11th, latitude 45°–13′N; longitude 32°–45′W; end of gale on the 13th; highest force of wind 64 miles an hour; wind shifted from southwest to west by north on the 9th and from west to southwest by west on the 11th. Barometer started rising and reached 29.66 inches with signs of storm center having passed at noon on the 9th; then the barometer again began to fall and later there was a slight shift of wind to left with increasing force; intermittent rising and falling barometer until 6 a. m. on the 12th, when steady rise began."

On the 10th and 11th this disturbance remained in nearly the same position as on the 9th, with but slight diminution in the force of wind, while on the 11th hail was reported in the southwesterly quadrants.

The weather maps, May 12–20 (Charts IX–XVII) show the conditions prevailing on these days.

From the 21st to the 26th the atmospheric circulation was comparatively sluggish over the greater part of the ocean, and fog occurred on the Banks of Newfoundland and off the European coast on several days during this period. There were exceptions to these conditions, however, as on the 22d a vessel about 5 degrees east of Horta, Azores, as well as the observatory at that place registered southwesterly gales of over 60 miles an hour, while another vessel near latitude 47, longitude 23, also experienced heavy weather on that day.

The weather of the last few days is shown on the weather maps of the North Atlantic, Charts XVIII–XXII.

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NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—Over by far the greater part of Great Britain a marked predominance of anticyclonic weather resulted in one of the warmest and driest Mays on record. In Ireland, where the conditions were influenced very frequently by cyclonic systems moving over the Atlantic, the weather was of a more normal character. The effect of warm air blowing over the cool sea surface was seen in a considerable prevalence of coastal fog. An absolute drought was experienced during the latter part of the month at many widely distributed stations. It was most marked in the Thames Valley, where no rain fell after the 11th except at a few stations where the drought was broken by slight precipitation on the 25th. The general rainfall expressed as a percentage of the average was: England and Wales, 41; Scotland, 41; Ireland, 120; British Isles, 62.

France.[1]—"Generally good weather; greatly improved crop prospects."

Spain.[1]—"Weather has not been altogether favorable for crops, the excessive rains causing some floods."

Italy.[1]—"A return of fine and warmer weather has favored crops."

Germany.[1]—"Weather has been fairly seasonable."

Argentina.—Weather continues fine and further progress has been made in the picking of the corn crop. Ploughing for the new crop of wheat has also been active under the favorable weather conditions, recent precipitation having put the soil in good condition.—*New York Ev. Post, May 23, 1919.*

[1] From Broomhall cabled report, New York Ev. Post, May 28, 1919.

DETAILS OF WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By E. H. BOWIE, Supervising Forecaster.

During the month of May the forecaster dealt with eleven primary low-pressure areas, and of these four belonged to the Alberta type, four to the South Pacific type, and three unclassified, made their first appearance over southern Canada, east of the 90th meridian. Moreover there were five secondary low-pressure developments which became well-defined low-pressure areas. One of these formed over southern Arizona, one over Kansas, one over Wisconsin, one over North Carolina, and one off the New Jersey coast. The low-pressure areas followed no well-defined course, and their directions and speed of movements were markedly variable, except during the first decade of the month when their directions were toward the east-northeast and their speed of movement rapid. At other times their rates of progress were slow and their directions of progress erratic, from which it is inferred that the general eastward drift of the atmosphere was not at all uniform as to speed and direction.

There were eleven high-pressure areas charted during May, and of these one made its first appearance off the California coast, one off the north Pacific coast, four entered the United States from Canada west of the 100th meridian, and five appeared over southern Canada east of the 95th meridian. The two high-pressure areas that made their appearance off the Pacific coast preserved their identity, crossed the United States, and reached or passed off the south Atlantic coast, and the others passed eastward, north of latitude 40 and disappeared over the Atlantic Ocean.

THE WEATHER ELEMENTS.

By P. C. Day, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, July 1, 1919.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for May, 1919, are graphically shown on Chart VII, while the means at the several stations, with the departures from the normal, are shown on Tables I and III.

The general atmospheric circulation was not marked by extremes of either high or low pressure, although areas of moderately low pressure without well-defined movements formed at frequent intervals over the central and eastern districts. These favored much cloudiness and frequent local showers, heavy occasionally, but usually not sufficient to bring the total fall for the month greatly above the normal.

The average pressure for the month was below normal over all portions of the United States, save from the Central Plains northeastward to the Great Lakes, and locally in northern New England and the far Northwest, where the monthly averages were slightly higher than normal. In Canada the monthly pressure was below normal in the northwestern districts but slightly above to the northward of the Great Lakes and thence eastward to the Maritime Provinces.

The greatest negative departures were mainly in the southeastern districts, where locally the pressure readings were below 30 inches during nearly the entire second and third decades of the month. In Canada the negative departures were rather large in the western districts, increasing toward the north.

The general pressure distribution favored southerly winds in the Plains region and over much of the Atlantic and Gulf Coast States. In the Lake region and generally over the Ohio and Mississippi Valleys the winds were mostly from northerly points, while to the westward of the Rocky Mountains they assumed their usual variable courses, due frequently to the influence of local topography, although along the immediate Pacific coast they mainly had strong westerly components.

TEMPERATURE.

The month opened with cool weather in the Great Plains and Rocky Mountain regions and generally moderate spring weather in other districts. Only slight temperature changes occurred until about the middle of the first decade, when there were sharp falls in the northern districts between the Rocky Mountains and the Great Lakes, due to high pressure moving eastward over Canada. This cool area advanced rapidly toward the Atlantic coast and frosts occurred generally over the more northern districts. Cool weather continued very generally over the central and northern districts east of the Rocky Mountains throughout the remainder of the first decade, and over most eastern districts, during the early part of the second decade. In portions of the Plateau region, however, the temperature had remained above normal continuously since the first of the month.

By the middle of the second decade the temperatures had risen to about normal in all parts of the country where cool weather had prevailed and only slight changes occurred thereafter during the remainder of the decade. During the early part of the last decade temperatures were without marked variations and were generally above or only slightly less than normal, but about the 25th there was a considerable warming up in the Northwest and warmer weather gradually overspread all central and northern districts, continuing until the end of the month from the Mississippi Valley eastward.

In the far West high pressure overspread the northern and central districts toward the latter part of the month and at the end decidedly cold weather prevailed over these districts, the temperature falling below the normal for the first time during the month at points in the Central Plateau. Temperatures nearly 10° below freezing were reported from exposed points and snows occurred locally in the mountain districts.

For the month as a whole the temperature was below the normal in the Ohio and Mississippi Valleys, the Gulf States, and the middle and southern Great Plains. On the other hand, May was warmer than normal in the Atlantic coast and Appalachian Mountain districts, along the northern border from the Upper Lakes westward, and from the Rocky Mountains to the Pacific coast, except for a small area in the far Northwest, where there was a slight deficiency.

In portions of the Middle Plateau the maximum temperatures during May were the highest of record for that month, and the daily means were above normal continuously except for the last two days. Over large areas in central and northern districts between the Appalachian and Rocky Mountains May was the first month since October, 1918, inclusive, with monthly mean temperatures below the normal.

PRECIPITATION.

The month opened with an area of rain covering all districts east of the Mississippi, except the extreme northeast and southeast sections. With the eastward movement of the storm center during the 2d the rain area extended into these sections also. During the 2d and 3d an area of rain overspread the central and northern Plains, extending during the following day or two into the Lake region and Ohio Valley and thence to New England, the falls being heavy in the middle Mississippi Valley and Great Lakes region. An offshoot of the storm extended into the Gulf States, causing some heavy rains in Texas and the lower Mississippi Valley. Local showers occurred in many districts east of the Rocky Mountains about the 6th, and during the following three or four days well-distributed and generous rains occurred in nearly all portions of the country from the Rocky Mountains eastward.

During the middle portion of the month precipitation was mostly in the form of local showers, occasionally heavy, but confined principally to the central and eastern districts. Near the end of the second decade a considerable area of rain overspread the Plains region with its center located near the middle Mississippi Valley, and from thence, during the following few days general rains extended into nearly all eastern districts. At the same time a rain area developed in the far Southwest and by the morning of the 24th heavy rains had fallen over much of western Texas, New Mexico, Arizona, and portions of adjoining States. This rain area extended into the Gulf States by the 25th, and frequent showers prevailed over these regions during the remainder of the month, some heavy falls being reported from southern Florida on the 31st.

Over the central and northern portions of the country the latter part of the month was comparatively free from rains until about the end when showers again set in over the central and northern Plains and in the upper Mississippi Valley.

The monthly precipitation was above normal at practically all points from Texas eastward and northeastward to the Atlantic coast, the excesses being quite large in the west Gulf States and over the southern drainage of the Ohio. Precipitation was likewise above normal, but to a lesser extent, over portions of the far Southwest and at points in the Dakotas. From the middle Plains States west and northwest to the Pacific coast the monthly precipitation was less than normal and in portions of the far West and Northwest the month was unusually dry, in northern California particularly it was the driest May in nearly half a century. This deficiency was greatly accentuated by the general lack of precipitation during the preceding month.

The month as a whole was one of much cloudiness and frequent, though generally not heavy showers, in the districts from the Mississippi River eastward. This was particularly true in the middle Gulf States and the southern portions of the Ohio Valley.

RELATIVE HUMIDITY.

The departures of the monthly averages of relative humidity closely followed those of the precipitation, the areas showing an excess of precipitation having likewise an excess of humidity, and negative departures of precipitation were associated with similar departures of humidity. Despite the generally moist condition of the atmosphere over eastern districts, some unusually low humidity values were observed. This was particularly marked over New England at noon of the 13th when the humidity was as low as 14 per cent at Portland, Me., and 23 per cent at Boston. Westerly winds prevailed at the time but a storm had only recently passed over that region and the barometer was still below 30 inches, and with no high pressure to the westward. On the same date unusually low humidity was recorded in the extreme western part of the country. At Mount Tamalpais, Calif., nearly 2,500 feet above sea level, the humidity at the morning observation, 5 a. m., local standard time, was only 6 per cent. This with strong southwest winds, a complete covering of upper clouds and dense fog below the summit.

LOCAL STORMS.

Nearly all sections of the country were free from high winds of any character and less than the usual amount of damage or loss was sustained from this cause. Indications of a tornado were observed in the vicinity of Mobile, Ala., on the 26th, several persons being injured, but no material loss was sustained. High winds at Atlanta, Ga., on the 7th, caused considerable damage, but no lives were lost.

Average accumulated departures for May, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	° F.	° F.	° F.	In.	In.	In.	P. ct.		P. ct.	
New England	55.6	+1.1	+13.6	4.55	+1.20	+2.70	6.0	+0.4	74	− 2
Middle Atlantic	62.4	+0.8	+13.2	4.50	+1.00	+0.10	5.2	+0.1	74	+ 3
South Atlantic	70.7	+0.9	+ 5.7	4.19	+0.40	−3.00	5.8	+1.2	80	+ 7
Florida Peninsula	77.5	−0.5	− 1.7	8.17	+3.90	+6.90	5.5	+1.2	77	+ 3
East Gulf	70.4	−1.8	− 1.7	5.89	+2.40	+5.60	6.2	+1.4	78	+ 6
West Gulf	70.4	−2.5	− 3.0	5.31	+1.20	−0.20	5.9	+1.0	79	+ 4
Ohio Valley and Tennessee	62.6	−2.4	+ 5.1	4.87	+1.20	−1.30	6.7	+1.6	73	+ 5
Lower Lakes	55.9	−1.6	+11.2	4.22	+1.10	+0.40	5.9	+0.5	72	+ 2
Upper Lakes	52.8	+0.2	+17.7	3.15	−0.30	−0.70	4.7	−0.4	71	− 1
North Dakota	56.3	+2.0	+18.0	3.42	+1.00	+0.60	4.0	−1.4	64	− 1
Upper Mississippi Valley	59.3	−2.7	+12.9	3.77	−0.40	−0.80	6.1	+0.8	71	+ 3
Missouri Valley	60.3	−1.7	+15.0	3.28	−1.00	−1.00	5.4	0.0	69	+ 4
Northern slope	54.4	+1.4	+13.1	1.35	−1.00	−2.10	4.6	−0.9	56	− 5
Middle slope	61.4	−1.4	+ 4.6	3.04	−0.80	−1.80	5.8	+0.9	69	+ 7
Southern slope	68.2	−2.5	− 6.3	3.21	+0.50	+3.30	4.7	+0.4	69	+15
Southern Plateau	67.2	+1.3	− 6.0	0.78	+0.50	+0.40	2.6	0.0	40	+ 9
Middle Plateau	61.2	+4.7	+ 5.5	0.99	−0.20	−1.80	3.5	−0.6	39	− 7
Northern Plateau	57.1	+0.2	+ 9.4	0.49	−1.20	−1.40	5.2	+0.1	48	− 8
North Pacific	53.7	−0.2	+ 4.9	2.44	−0.30	+2.00	5.6	−0.8	72	− 5
Middle Pacific	58.8	+1.2	+ 0.3	0.28	−1.00	−1.60	3.0	−0.9	64	− 4
South Pacific	62.7	+0.6	+ 3.0	0.20	−0.40	−3.70	4.8	+0.8	72	+ 3

Winds of 50 mis./hr. (22.4 m./sec.) or over during May, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Atlanta, Ga.	7	60	w.	North Head, Wash	11	57	s.
Block Island, R. I.	10	53	e.	Do.	14	50	s.
Buffalo, N. Y.	2	60	sw.	Do.	25	57	s.
Del Rio, Tex.	23	50	e.	Do.	26	64	se.
Jacksonville, Fla.	20	54	sw.	Pensacola, Fla.	26	62	sw.
Do.	27	53	s.	Point Reyes Light, Calif.	8	60	nw.
Mount Tamalpais, Calif.	7	66	nw.	Do.	9	62	nw.
Do.	8	84	nw.	Do.	10	61	nw.
Do.	9	67	nw.	Do.	11	61	nw.
Do.	10	53	nw.	Do.	12	62	nw.
Do.	11	84	nw.	Do.	26	56	nw.
Do.	12	52	nw.	Do.	28	72	nw.
Do.	15	56	nw.	Do.	29	83	nw.
Do.	25	56	nw.	Do.	30	57	nw.
Do.	26	55	nw.	Sandy Hook, N. J.	10	56	ne.
Do.	28	50	nw.	Tatoosh Island, Wash.	26	62	s.
New York, N. Y.	5	55	nw.				

SPECIAL FORECASTS AND WARNINGS—WEATHER AND CROPS.

WEATHER WARNINGS.

By EDWARD H. BOWIE, Supervising Forecaster.

[Dated: Weather Bureau, Washington, May 19, 1919.]

FORECASTS FOR THE U. S. NAVY IN CONNECTION WITH THE FIRST TRANSATLANTIC SEAPLANE FLIGHT.

Under an agreement between the United States Weather Bureau and the United States Navy Department, the Weather Bureau undertook the forecasting of the meteorological conditions along the route to be followed by the seaplanes from the time they left the Rockaway flying field, Long Island, N. Y., until they reached the Azores. The forecasts were issued thrice daily based on observations taken at 8 a. m., 1 p. m., and 8 p. m., seventy-fifth meridian time, and were given to the Navy Department in Washington, for transmission to their destinations. Moreover, synoptic reports from a considerable number of Weather Bureau and Canadian stations at these hours were also furnished the Navy Department for transmission to Rockaway, Halifax, and Trepassey Bay, when the seaplanes were at these points. The United States Navy furnished meteorological observations from a number of points in western Europe and from naval vessels along the course from Newfoundland to the Azores.

The start of the seaplanes NC–1, NC–3, and NC–4 was made from Rockaway the morning of the 8th, two of them, the NC–1, and NC–3 reaching their destination, Halifax, the afternoon of the same day. The NC–4 developed engine trouble and put into Chatham, Mass. The forecast issued the morning of the 8th was as follows:

Moderate northwest and west winds. Fair weather to-day. Friday fresh north to east winds, cloudy weather with rain over southern half of course.

The evening of the 9th the following forecast was made for the seaplanes for the course between Halifax and Trepassey Bay:

Weather favorable for flight Saturday. Gentle variable winds. Fair weather. Wind velocity less than fifteen miles an hour.

The morning of the 10th, the forecast for the same course read:

Fair weather Halifax to Newfoundland. Gentle variable winds, except moderate west and northwest off south coast of Newfoundland.

The flight from Halifax to Trepassey Bay was made on the 10th and the two seaplanes, the NC–1 and NC–3, reached their destination, Trepassey Bay, the afternoon of the same day.

In the meantime, the seaplane, NC–4, at Chatham, Mass., had made ready for a renewal of the flight to Halifax, but it was held there for several days because of adverse wind and weather conditions. On the evening of the 13th the following forecast was sent the commander of seaplane NC–4 at Chatham, Mass.

Conditions favorable for start from Chatham for Halifax Wednesday morning (the 14th). Moderate to fresh westerly winds and fair weather.

On the morning of the 14th the following forecast was sent to the same address:

Moderate westerly winds, fair weather Chatham to Halifax. Conditions extremely favorable for start this morning.

The flight was made to Halifax on this day under favorable conditions. On the evening of the 14th the following forecast was issued for the course Halifax to Newfoundland for the NC–4 at Halifax:

Gentle and moderate variable winds mostly north and partly cloudy weather Halifax to Newfoundland. Some doubt as to fog off south coast of Newfoundland. Advices concerning this should be had before starting from Halifax Thursday morning.

The NC–4 left Halifax on the 15th and arrived at Trepassey Bay the same afternoon.

From the time of the arrival of the NC–1 and NC–3 at Trepassey Bay on the 10th until the 16th the weather and wind conditions over the course between Newfoundland and the Azores were unfavorable and were forecast accordingly. On the 15th the following forecast was sent the commander of the seaplane squadron at Trepassey Bay:

Wind and weather conditions over the course (Newfoundland to the Azores) will improve during Friday and Saturday. Wind will be west and fresh and possibly strong. Weather will be fair. Above based on incomplete reports from the ocean. Advise start by Friday night. Later information will be sent you Friday.

On Friday the following forecast was sent the commander of the seaplanes at Trepassey Bay:

Surface winds fresh and possibly strong west-southwest and upper winds fresh to strong west over course between Newfoundland and the Azores, some clouds, fair visibility, and rising pressure. Conditions favorable for start.

The seaplanes left Trepassey Bay the afternoon of the 16th for the Azores. The *NC–4* reached the Azores the late forenoon of the 17th. The *NC–1* and *NC–3* landed in the vicinity of the Azores the morning of the 17th, but were unable to rise from the water and resume their flight. The landings were necessary according to press reports—because of low clouds and mist.

At the time the seaplanes were preparing for the transatlantic flight, the United States Navy dirigible *C–5* was ready to make a flight from Cape May to St. Johns, Newfoundland, with the tentative purpose of extending the flight across the ocean in the event that a satisfactory trip was made to Newfoundland. This airship left Cape May, it is understood, on the 8th of May, encountered unfavorable weather and put in at Montauk Point, Long Island, N. Y., whence it started for St. Johns, Newfoundland, on the 14th. On the 13th the following information was sent the United States naval air station, Montauk Point, N. Y.:

Conditions favorable for start from Montauk Point Wednesday morning. Moderate to fresh westerly winds and fair weather.

The *C–5* reached its destination, St. Johns, Newfoundland, on the morning of the 15th. In the afternoon of that day during a squall it broke its moorings and drifted eastward over the Atlantic Ocean and was lost.*

WASHINGTON FORECAST DISTRICT.

Storm warnings on the Great Lakes: Southwest-storm warnings were displayed at 10 a. m. of the 1st on Lakes Erie and Ontario, in connection with a low-pressure area which was central at 8 a. m. of the 1st over northern Indiana. This disturbance moved rapidly northeastward and strong southwest winds and gales occurred as

* See "Official story of C-5 dirigible's record flight to Newfoundland," Aerial Age Weekly, June 16, 1919, pp. 683, 702.—Ed.

forecast. Moreover, strong westerly winds also occurred on the Upper Lakes. The highest wind velocity in connection with this storm, 60 miles an hour from the southwest, occurred at Buffalo on the 2d.

On the 3d at 10 a. m. southeast-storm warnings were displayed on Lake Michigan and northeast warnings on Lake Superior, except at Sault Ste. Marie. At 4 p. m. of the same day southeast warnings were displayed on Lake Huron. These warnings were ordered at the time that a disturbance of moderate intensity was central over Nebraska. This disturbance moved northward and although squally weather and fresh and strong winds occurred at some points, no general storm winds occurred in connection with it.

On the 17th at 9:30 a. m. northwest-storm warnings were ordered for Lake Ontario and Lake Erie at and east of Cleveland in connection with a low-pressure area that was central at 8 a. m. over Georgian Bay. Strong westerly winds occurred between 8 a. m. and 8 p. m. of the 17th and the signals were lowered at 9:30 p. m. of the same day.

On the 20th at 9:30 a. m. northwest-storm warnings were displayed on Lake Huron between Saginaw and Port Huron and on Lake Erie, Detroit to Cleveland, and at the same time southeast warnings were ordered on eastern Lake Erie and Lake Ontario. At 8 a. m. of this date a storm of considerable intensity was central over Ohio. Strong winds, rain and thick weather occurred during the 20th, but the disturbance under consideration rapidly lost intensity, and during the night of the 20th the winds moderated on the Great Lakes.

Storm warnings on the Atlantic coast.—On the 1st when a disturbance of marked intensity was central over northern Indiana, southwest-storm warnings were displayed at 10 a. m. at and between Cape Henry, Va., and Boston, Mass. This disturbance moved northeastward during the succeeding 36 hours, and strong south and southwest winds with rain and fog prevailed over that section of the Atlantic coast where warnings were displayed.

On the 9th at 10 p. m. northeast-storm warnings were displayed on the Atlantic coast at and between Delaware Breakwater, Del., and Provincetown, Mass. At 8 p. m. of this date a disturbance was central over eastern Tennessee and an extensive high-pressure area covered the region of the Great Lakes, the St. Lawrence Valley, and New England. Strong easterly winds and gales and rain set in the night of the 9th over the section of the coast where warnings were displayed, and these conditions persisted through the 10th and 11th and extended northward to Eastport, Me., on the 12th. In the meantime the section of the coast covered by northeast warnings was extended northward to Portland, Me., at 10 a. m. of the 10th and to Eastport, Me., at 10 a. m. of the 12th. This disturbance passed northeastward, and the morning of the 14th its center was over the Gulf of St. Lawrence.

On the 17th at 9:30 a. m., southwest warnings were displayed along the coast from Sandy Hook, N. J., to Eastport, Me. At 8 a. m. of this date a low-pressure area of considerable intensity was over the Great Lakes and moving east-northeastward. Strong southerly winds, rain, and thick weather prevailed during the afternoon and night of the 17th off the middle Atlantic and New England coasts, the highest wind velocity reported being 48 miles an hour from the south at New York City.

On the 20th at 6 p. m., southwest-storm warnings were displayed on the Atlantic coast between Norfolk, Va., and Boston, Mass. At 1 p. m. of this date a low-pressure area of considerable intensity was over Indiana and moving eastward. This disturbance, however, decreased in intensity as it moved eastward, and at 9:30 a. m. of the 21st the warnings on the coast were lowered.

No storm warnings were displayed during the month south of Cape Henry, neither were warnings other than small-craft warnings displayed on the Gulf coast east of New Orleans.

In connection with the work of the Weather Bureau on the Great Lakes a communication recently received from Capt. John Hyatt, of the *City of Alpena*, one of the boats of the Detroit & Cleveland Navigation Co., is given below:

"I want to thank you and the radio station at Alpena for the very fine service rendered me in the past five seasons. The weather reports and currents furnished me have never failed, which means everything to the safety of ships in bad weather."

Frost warnings.—In the Washington forecast district frost warnings were issued on the 5th for Indiana and Michigan; on the 6th for northern New England and the northern and central parts of eastern New York; on the 7th and 8th for Michigan and northern Indiana; on the 10th and 11th for Michigan; on the 12th for West Virginia, lower Michigan and the eastern part of upper Michigan; on the 12th and 13th for the cranberry bogs of New Jersey; on the 13th for New England, New York, and Pennsylvania; on the 17th for Michigan; on the 18th for parts of New York and New England; and on the 20th for Michigan.

WARNINGS FROM OTHER DISTRICTS.

Chicago, Ill., forecast district.—No frost warnings were issued or required for Illinois, Minnesota, Iowa, Missouri, or Kansas, but warnings were issued on the 6th, 30th, and 31st for portions of the northern Rocky Mountain region or northern Plains States, and on the 5th, 7th, 15th, 16th, 17th, 19th, 20th, and 21st for portions of Wisconsin. No warnings were issued for the cranberry bogs until the 15th, on account of the backwardness of the season, and those issued thereafter were not well verified because of cloudiness.

Special fire-weather forecasts were sent to the forest rangers at a number of points in northern Minnesota, beginning on the 29th, the situation in that section having become serious on account of protracted hot, dry weather.—*Chas. L. Mitchell.*

New Orleans, La., forecast district.—With rather high air pressure prevailing during much of the month in the northeastern portion of the country and low pressure over the southwestern States, conditions in this forecast district were favorable for considerable cloudiness and comparatively cool weather, and it is worthy of note that the highest temperatures were below 90° at all regular stations in the central and eastern portions of the district.

The winds of gale force mostly attended thunderstorms. No general storm occurred without warning.

Small-craft warnings were displayed on the Texas coast on the 6th and were justified.

Southeast-storm warnings were ordered on the morning of the 24th from Morgan City, La., to Corpus Christi-Tex., because of a disturbance over southern Texas, moving northeast. Warnings stated that the disturb, ance would cause "strong southerly winds to moderate gales, with thundersqualls to-day, shifting to northwest on Texas coast to-night." The warnings were extended along the remainder of the Louisiana coast after midday special observations were obtained. Conditions occurred generally as forecast and squalls were severe in localities near the lower Sabine River.

No frosts were reported and there was but one frost warning. On the 4th a forecast of probably frost was issued for the Texas Panhandle and western Oklahoma. In this instance the area of high pressure moved eastward instead of southeastward and the pressure was low over the Plateau States on the 5th, preventing any decided temperature fall in this district.—*R. A. Dyke.*

Denver, Colo., Forecast District.—Pressure conditions were not favorable to the usual distribution of precipitation, the month being droughty on the middle eastern slope, while on the southeastern slope more precipitation than usual occurred. Temperature conditions prior to the closing days were unusually favorable, the cold snaps and sudden changes so common in the northern half of the district were notably absent and the subject of general comment. It is true frost warnings were issued on a few dates in the first half of the month for localities, but the damage, if any, was slight.

Decided changes in pressure distribution during the closing days brought a cold spell of unusual intensity for so late in the season. On the morning of the 30th the pressure was low from Arizona northeastward to the Dakotas while high pressure overlay the Pacific Northwest. Warnings of frost were issued for western Colorado and Utah, in expectancy of the development of a low center on the southeastern Rocky Mountain slope coincident with the southeastward movement of the front of the anticyclone. Although this distribution of pressure occurred the warning was fully justified only in the greater part of Utah; in Colorado sharp falls in temperature occurred, but it is doubtful whether frosts occurred in the valleys of western Colorado.

On the morning of the 31st warnings of frost or freezing temperatures were issued for western and northern Colorado, northern New Mexico, northeastern Arizona, and Utah. In addition to the warnings the distribution observer in the Gunnison district of Colorado was directed to advise orchardists. Frosts or freezing temperatures were confined to the areas to which warnings were sent; there was considerable variation in the intensity of the cold; in localities the freeze was destructive to important crops, while in others the damage was confined to garden truck and other tender vegetation.—*Fredk. H. Brandenburg.*

San Francisco, Calif., Forecast District.—This district was comparatively free from storm activity during the month of May, 1919. The low areas during the month entered the continent at a high latitude and except in western Washington there were but few rainy days. The feature of the month was the frequency with which troughs of low pressure formed over the Plateau region either from the passage of low areas through Alberta and Saskatchewan of from small secondary depressions developing over the valley of the Colorado in consequence of, and just subsequent to, the passage of a LOW in the north. The eastward movement of these troughs were followed by sharp falls in temperature and frequent frosts in the Plateau region. During the prevalence of one of these depressions over Nevada and Idaho on the 27th and 28th, very high temperatures occurred in those States, and the record for high May temperatures was broken at Pocatello on the 28th, when the maximum reached 94 degrees.

Live-stock warnings were issued on the 1st in eastern Oregon and Idaho, reading "Cold rains and gusty westerly winds to-night, Friday, and possibly Saturday." The rains did not occur, but strong winds and colder weather prevailed for the following two days.

Small-craft warnings were ordered on the Oregon and Washington coasts on the 13th; southwest-storm warnings were ordered from the Columbia River north on the 25th and 26th; and northwest-storm warnings were ordered at Point Reyes on the 29th.

Frost warnings were issued in eastern Oregon, eastern Washington, and Idaho on May 2, 3, 4, 5, 6, 12, and 17; in Washington, Oregon, and Idaho on May 10 and 30; and in Nevada on May 5, 6, 10, 12, and 30.

Fire-weather warnings were issued in California on the 31st, to the district forester for distribution, reading: "Moderate to strong drying northerly winds with high day temperatures next two or three days. Danger of forest fires in all California forests except probably Modoc and Mono. Supervisors should be warned." This warning was followed by a decided rise in temperature and strong northerly winds north of the Tehachapi. The wind did considerable damage to fruit and grain in some portions of the Sacramento Valley.—*G. H. Willson.*

RIVERS AND FLOODS, MAY, 1919.

ALFRED J. HENRY, Meteorologist in Charge.

Atlantic drainage.—Moderately heavy and long-continued showery weather over New York and northern Pennsylvania during the last decade of the month caused the small streams, particularly in western and southern New York, to overflow, thereby damaging highways and the roadbed of the railroads in that part of the State. Heavy rain was not general over a large area and therefore the floods were largely local.

South Atlantic drainage.—General and heavy rains over the Atlantic drainage of the southern Appalachians on May 6, 7, 8, 13, and 14 caused two distinct flood waves in the streams of that region, neither of which was particularly destructive.

Gulf drainage.—Only local flood stages occurred and there was not much damage.

Great Lakes drainage.—In the first decade of the month a general rainstorm passed northeastward across lower Michigan. The rivers of that section and also of northern Indiana, including the Wabash, reached flood stages locally without serious damage.

Mississippi drainage (Mississippi proper).—As noted on the April, 1919, REVIEW, the Mississippi was in flood at the close of the month in that stretch of the stream between Keokuk, Iowa, and Louisiana, Mo. Moderately heavy rains fell over northeastern Missouri, southeastern Iowa, and western Illinois on the 2d, 3d, and 4th. These rains while not particularly heavy came at the time when the river was at a high stage. As a result, the river rose to the highest stages of the year, and the highest since 1903 between Quincy, Ill., and Louisiana, Mo. Warnings were issued by the Weather Bureau on May 3 and repeated with amplification on May 5, 6, and 7. Immediately protective measures were taken to guard against a failure of the levees protecting the farm lands back of them. The weak spots in the 52 miles of levee in the Hannibal, Mo., district were at once reinforced and a day and night patrol was established. This patrol was continued until the 14th when the stage of the river had passed below 16 feet on the Quincy, Ill., gage. The only serious flooding which occurred was due to an incompleted levee near Louisiana, Mo. About 7,000 acres of land in that section were flooded. The lower river was not in flood during the month except locally at Arkansas City, Ark.

The Rio Grande.—Melting snows in sheltered places in the Rocky Mountains was responsible for high water in the Rio Grande in New Mexico from the 6th to the 10th and again from the 24th to the 27th.

Pacific coast drainage.—Due to the temperatures in the higher regions of the Middle Rocky Mountains the flow of the Colorado was less than usual.

The Columbia passed above flood stage at Marcus, Wash., on the 26th and at Vancouver on the same date. The flood at the last-named came out of the Willamette.

Estimated loss by flood, May, 1919.

District.	Bridges, highways, and railroads.	Crops and gardens (prospective).	Farm property, fences, live stock, etc.	Suspension of business.	Value of warning.
Middle Atlantic	$50,000	$20,000	$1,000	$10,000	.....
South Atlantic	2,500	4,000	1,190	1,963	$91,000
Hannibal, Mo.	8,500	140,000	500	.....	75,000
Little Rock, Ark.	.....	10,000	.....	.....	.....
Total	61,000	174,000	2,690	11,963	166,000

TABLE I.—*Flood stages in the Atlantic drainage for the month of May 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Connecticut:	*Feet.*			*Feet.*	
Hartford, Conn.	16	23	26	19.1	24
White River Junction, Vt.	13	23	23	13.3	23
Santee:					
Rimini, S. C.	12	4	4	12.0	4
Do.	12	8	29	16.4	19
Ferguson, S. C.	12	9	26	13.8	20
Do.[1]	12	29	31	12.5	29
Catawba:					
Catawba, S. C.	11	14	15	12.5	14
Wateree:					
Camden, S. C.	24	9	10	27.7	9
Do.	24	15	16	28.1	15
Broad:					
Blairs, S. C.	15	14	15	17.5	15
Saluda:					
Pelzer, S. C.	7	13	13	7.8	13
Chappell, S. C.	14	15	16	16.6	15

[1] Continued into June.

TABLE II.—*Flood stages in the East Gulf drainage for the month of May, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Tombigbee:	*Feet.*			*Feet.*	
Demopolis, Ala.	30	31	31	30.0	31

TABLE III.—*Flood stages in the Great Lakes drainage for the month of May, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Maumee:	*Feet.*			*Feet.*	
Fort Wayne, Ind.	15	5	7	19.0	6
St. Joseph:					
Montpelier, Ohio.	10	5	8	12.6	6
Tittabawassee:					
Midland, Mich.	12	5	5	12.9	5
Grand:					
Eaton Rapids, Mich.	5	5	7	5.2	6
Grand Ledge, Mich.	6.5	6	6	6.8	6
Grand Rapids, Mich.	11	7	9	12.6	7
East Lansing, Mich.	8	4	7	9.1	6
Cedar:					
Williamton, Mich.	10	5	6	10.1	5

TABLE IV.—*Flood stages in the Mississippi (Ohio basin) drainage for the month of May, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Shenango:	*Feet.*			*Feet.*	
Sharon, Pa.	9	10	12	12.5	10
Tuscarawas:					
Norris Point, Ohio.	8	11	12	10.8	12
Scioto:					
Circleville, Ohio.	7	10	11	7.8	11
Green:					
Lock No. 6, Brownsville, Ky.	30	11	12	33.3	11
Lock No. 4, Woodbury, Ky.	33	10	15	42.95	12
Lock No. 2, Ramsey, Ky.	34	14	20	36.9	14
Wabash:					
Lafayette, Ind.	11	5	8	17.2	6
Mount Carmel, Ill.	15	12	15	16.2	13
North Fork of Holston:					
Mendota, Va.	8	10	10	8.1	10

TABLE IV.—*Flood stages in the Mississippi (Ohio basin) drainage for the month of May, 1919*—Continued.

MISSISSIPPI AND TRIBUTARIES EXCEPT THE OHIO.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Mississippi:	*Feet.*			*Feet.*	
Keokuk, Iowa	14	1	1	14.3	1
Do	14	4	12	17.4	8
Warsaw, Ill	17	1	1	17.2	1
Do	17	4	12	20.4	8
Des Moines:					
Ottumwa, Iowa	10	4	8	14.2	7
Mississippi:					
Quincy, Ill	14	1	15	19.7	8
Hannibal, Mo	13	1	17	20.1	8
Louisiana, Mo	12	1	16	17.8	9
Grafton, Ill	18	1	3	18.7	1
Do	18	7	17	21.4	11–12
Alton, Ill	21	8	16	24.1	11
Arkansas City, Ark	42	21	[1] 31	44.1	29–30
Illinois:					
Morris, Ill	13	4	10	15.5	6
Peru, Ill	14	4	27	19.0	8
Henry, Ill.[1]	7	1	31	13.3	10–11
Peoria, Ill	16	5	28	19.9	11–12
Havana, Ill.[1]	14	7	31	16.1	12–16
Beardstown, Ill.[1]	12	1	31	16.5	16
Pearl, Ill	12	1	30	15.7	13
Grand:					
Chillicothe, Mo	18	4	11	29.0	6
Brunswick, Mo	10	6	12	15.3	8
Osage:					
Warsaw, Mo	22	18	18	23.2	18
Do	22	20	20	22.0	20
Yazoo:					
Yazoo City, Miss	25	1	9	27.4	1
Smokey Hill:					
Lindsborg, Kans	19	6	6	19.0	6
Do	19	16	16	20.0	16
Do	19	19	19	20.0	19
Neasho:					
Oswego, Kans	17	21	21	18.2	21

[1] Continued into June.

TABLE V.—*Flood stages in the West Gulf drainage for the month of May, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Trinity:	*Feet.*			*Feet.*	
Dallas, Tex	25	18	18	25.1	18
Do	25	27	29	28.8	28
Guadalupe:					
Victoria, Tex	16	11	12	18.0	11
Do	16	15	15	16.8	15
Do	16	27	29	20.8	28

TABLE VI.—*Flood stages in the Pacific drainage for the month of May, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Kings:	*Feet.*			*Feet.*	
Piedra, Cal	12	29	29	12.0	29

TABLE VII.—*Flood stages in the Pacific (Eel River basin) drainage for the month of May, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Columbia:	*Feet.*			*Feet.*	
Marcus, Wash.[1]	24	26	31	27.2	31
Vancouver, Wash.[1]	15	26	31	18.7	31
Kootenai:					
Bonners Ferry, Idaho[1]	26	26	31	28.7	30
Willamette:					
Portland, Oreg.[1]	15	26	31	18.1	31

[1] Continued into June.

MEAN LAKE LEVELS DURING MAY, 1919.

BY UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., June 4, 1919.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during May, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.25	581.38	573.69	247.27
Above or below—				
Mean stage of April, 1919	+0.23	+0.36	+0.64	+0.84
Mean stage of May	+0.57	−0.28	+1.52	+0.14
Average stage for May, last 10 years	+0.35	+0.86	+1.04	+0.59
Highest recorded May stage	−0.80	−2.14	−0.73	−1.68
Lowest recorded May stage	+1.43	+1.82	−2.38	+2.31
Average relation of the May level to—				
April level	.....	+0.3	+0.4	+0.3
June level	.....	−0.3	−0.2	−0.2

* Lake St. Clair's level: In May, 576.38 feet.

EFFECT OF WEATHER ON CROPS, MAY, 1919.

By J. WARREN SMITH, Meteorologist in Charge.

Farm work.—Frequent rains and resulting wet soil during most of the month from the central Plains States eastward were unfavorable for farm work, and plowing and planting were much retarded, while like conditions combined with wet soil at the beginning of the month delayed work in portions of the South, particularly in the western Gulf districts. In other sections of the country the month was generally favorable for outdoor operations, and farm work progressed satisfactorily, especially in the more western States.

Winter grains.—The month was generally favorable for the development of winter grains, and these crops made good to excellent progress in practically all of the principal producing sections. In some of the less important areas, however, the latter part of the month was unfavorable, particularly in the central and northern Rocky Mountain districts and in Montana, where dry weather and high temperatures produced harmful results. The growth of winter wheat was rank, and there were some complaints of lodging in the southern Great Plains area and in some central valley States.

Spring crops.—Spring grains made satisfactory progress in most sections during the month under the influence of favorable weather, although the seeding of oats was much delayed in some northeastern sections on account of continued wet soil.

It was too cool and wet for corn in much of the principal corn belt; planting was delayed and germination hindered in many sections. It was more favorable for this crop in most of the South, however, and satisfactory advance was made.

It was also too cool and wet for cotton, and that crop made unsatisfactory advancement, except for fairly good progress in some of the more eastern portions of the belt. It was especially unfavorable for cotton west of the Mississippi River.

Truck crops.—The cool, cloudy weather, with frequent rains, during much of the month in most central and northern districts produced conditions unfavorable for planting and growth of truck crops, but these made better progress in the more southern States, particularly in the southeast. Potatoes and other cool weather crops made generally good advance, however, where the soil was not too wet.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation, by sections, May, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	69.2	−2.4	Ozark	93	3	Valley Head	40	12†	6.07	+2.05	Citronelle	11.98	Dadeville	3.23
Arizona	67.8	+2.4	Sentinel	106	28†	Fort Valley	25	6	0.65	+0.37	Spring Valley R. S.	3.73	2 stations	0.00
Arkansas	66.8	−2.3	Pine Bluff	96	31	Bergman	38	21	6.01	+1.11	Alicia	11.15	Murfreesboro	1.82
California	63.3	+1.2	Greenland Ranch	112	27	2 stations	20	4†	0.32	−0.90	Crescent City	3.04	31 stations	0.00
Colorado	53.2	+1.8	Burlington	97	30	Fairplay	8	31	0.09	−0.07	North Lake	3.70	Spicer	9.02
Florida	75.6	−0.4	3 stations	98	25	Garniers (near)	46	22	6.45	+2.62	2 stations	14.97	Pinellas Park	2.29
Georgia	71.4	−0.5	Statesboro	98	25	Tate	39	22	4.66	+1.49	Thomasville	8.02	Covington	1.56
Hawaii (April)	71.0	+1.0	Mahukona	94	6	Glenwood	44	30	3.95	−3.58	Eke Maui	18.50	4 stations	0.00
Idaho	54.6	+2.1	Glenn's Ferry	105	28	Irwin	12	6	0.78	−1.16	Prichard	5.24	Buhl	0.00
Illinois	59.8	−3.0	Streator	96	30	2 stations	33	2†	5.22	+1.15	Quincy	9.50	Hoopeston	3.10
Indiana	59.5	−3.0	Huntington	97	31	Laporte	30	15	4.69	+0.64	Elliston	7.17	Columbus	2.17
Iowa	58.2	−2.3	Cedar Rapids	93	30	4 stations	30	2	3.11	−1.46	Maquoketa	7.14	Fort Dodge	0.73
Kansas	61.3	−1.5	2 stations	90	3†	Blakeman	32	22	3.13	−1.04	Pleasanton	9.20	Wallace	0.32
Kentucky	63.9	−1.7	....do	95	29†	2 stations	35	12	6.05	+2.10	Franklin	11.62	Williamsburg	3.72
Louisiana	71.8	−2.1	5 stations	92	17†	Kelly	42	22	8.22	+4.08	Antioch	12.95	Plain Dealing	4.24
Maryland-Delaware	62.9	−0.1	Cumberland	97	31	Oakland	31	3†	5.42	+1.71	Ferry Landing	7.84	Western Port	3.33
Michigan	53.0	−0.7	Mackinaw	99	30	Norways	19	6	3.31	0.00	South Haven	5.75	Ironwood	1.07
Minnesota	56.0	+1.2	Grand Rapids	97	29	2 stations	20	4†	2.37	−1.14	Fergus Falls	4.36	Faribault	0.66
Mississippi	69.3	−2.6	5 stations	90	6	Port Gibson	44	22	7.96	+3.58	Leakesville	14.92	Grenada	4.31
Missouri														
Montana	53.6	+2.4	Lytle	102	28	Bowen	11	13	1.46	−1.05	Columbia Falls	3.85	Brenner	0.13
Nebraska	57.9	−1.2	2 stations	91	30	Merriman	22	7†	2.54	−1.07	Pawnee City	6.60	Imperial	0.80
Nevada	60.1	+5.2	Logandale	105	27	Vya	15	3	0.63	−0.22	Mina	2.21	2 stations	0.00
New England	55.6	+0.4	Bridgeport, Conn	95	29	2 stations	23	5†	4.89	+1.56	Canton, Conn	7.81	Bethlehem, N. H.	2.39
New Jersey	60.9	−0.6	2 stations	95	29	Charlotteburg	31	29	4.98	−1.23	Tuckerton	7.68	Sandy Hook	3.06
New Mexico	59.5	+0.3	....do	99	22†	2 stations	21	25†	1.76	+0.65	Bland	6.29	2 stations	0.04
New York	56.0	−0.2	3 stations	94	29†	Lake Placid Club	22	1	5.05	+1.54	Lauterbrunnen	8.39	Warwick	2.49
North Carolina	67.2	+0.5	Weldon	97	28	Highland	30	22	5.27	+1.17	Enfield	10.42	Wilmington	1.26
North Dakota	55.3	+2.7	Donnybrook	101	28	Hannah	16	5	3.30	+0.75	Steele	7.74	Marmarth	0.66
Ohio	58.6	−2.3	Millersburg	98	31	Bellefontaine	30	18	4.78	+1.13	Gallipolis	7.47	Wapakoneta	2.44
Oklahoma	66.0	−1.5	Sallisaw	94	5	Kenton	37	21	4.61	−0.86	Kingfisher	8.10	Newkirk	1.90
Oregon	54.7	+0.5	La Grande	100	20	2 stations	11	3†	1.17	−1.27	Newport	5.44	2 stations	0.00
Pennsylvania	59.5	+0.7	Johnstown	98	31	....do	27	3	5.80	+1.95	Center Hall	13.59	Pottstown	2.86
Porto Rico														
South Carolina	71.0	−0.4	Santuck	96	31	2 stations	42	3†	5.23	+1.72	Winthrop College	9.90	Charleston	1.69
South Dakota	56.2	+0.2	2 stations	94	27†	Bellefourche	24	4	2.79	+0.01	Faulkton	6.88	Orman	0.65
Tennessee	65.4	−1.7	....do	93	29†	Mountain City	33	3	6.52	+2.49	Huntingdon	12.75	Greeneville	3.11
Texas	70.7	−2.2	Encinal	109	31	2 stations	40	20†	5.31	+1.88	Hempstead	13.70	El Paso	0.14
Utah	59.0	+4.5	Wendover	103	28	Black's Fork	4	....	0.95	−0.33	Ogden	2.75	Green River	0.06
Virginia	64.4	−0.5	Lincoln	97	30	Burkes Garden	31	3	5.29	+1.49	Clarksville	9.00	Dry Bridge	3.28
Washington	54.3	−0.4	2 stations	96	21	Colfax	20	5	1.84	−0.32	Cedar Lake	10.45	Wenatchee	0.02
West Virginia	61.5	−0.9	Fairmont	100	31	Marlinton	30	19	5.25	+1.27	Camden-on-Gauley	10.71	Parsons	2.75
Wisconsin	54.0	−0.9	Iron River	96	29	2 stations	20	2†	2.84	−1.13	Waupaca	5.71	Cornucopia	0.78
Wyoming	52.1	+3.1	2 stations	97	29	Afton	4	15	0.68	−1.41	Kirtley	2.26	Basin	0.00

* For explanation of the following table and charts, see this REVIEW, January, 1919, pp. 52-53.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, May, 1919.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F*		° *F*	° *F*		° *F*	° *F*		° *F*	° *F*	%	*In.*	*In.*		*Miles*									*0–10*	*In.*	*In.*
New England.							**55.6**	**+ 1.1**											**74**	**4.55**	**+ 1.2**										**6.0**		
Eastport	76	67	85	29.90	29.98	+0.02	48.4	+ 1.5	74	14	56	37	3	41	32		44	39	75	3.98	+ 0.2	13	7,552	s.	46	ne.	12	5	13	13	6.8	0.0	0.0
Greenville	1,070	6	....	28.82	29.98	.....	51.0	.....	74	28	62	28	15	40	37					4.76	.....	13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Portland, Me	103	82	117	29.87	29.99	+ .02	54.2	+ 0.7	88	29	62	39	7	47	32		48	42	70	5.16	+ 1.5	15	7,364	s.	36	nw.	26	11	11	9	5.2	0.0	0.0
Concord	288	70	79	29.67	29.98	.00	56.0	+ 0.3	89	29	67	32	1	45	43					5.11	+ 2.0	14	3,777	n.	23	w.	5	17	6	8	4.1	0.0	0.0
Burlington	404	11	48	29.52	29.96	— .01	54.8	+ 0.9	78	29	64	33	1	46	28					3.54	+ 0.7	17	7,200	n.	42	s.	7	5	11	15	6.6	0.0	0.0
Northfield	876	12	60	.....	29.99	+ .02	52.6	— 0.9	81	29	64	26	1	41	40					4.26	+ 1.5	16	5,510	s.	30	ne.	23	5	13	13	6.8	0.0	0.0
Boston	125	115	188	29.83	29.97	— .01	59.1	+ 2.5	93	29	68	41	11	51	38		52	46	68	4.25	+ 0.7	13	7,794	e.	36	e.	15	5	15	11	6.4	0.0	0.0
Nantucket	12	14	90	29.95	29.96	— .03	53.4	+ 0.4	73	26	60	39	6	47	19		50	48	86	4.67	+ 2.0	13	12,343	sw.	48	e.	11	9	9	13	6.3	0.0	0.0
Block Island	26	11	46	29.93	29.96	— .03	53.9	+ 1.0	75	30	60	41	1	48	21		52	51	93	3.42	— 0.3	14	12,525	sw.	53	e.	10	8	6	17	6.8	0.0	0.0
Providence	160	215	251	29.79	29.96	— .02	59.3	+ 0.8	92	29	69	41	10	50	34		52	46	69	3.79	+ 0.3	15	9,242	s.	41	w.	5	10	12	9	5.3	0.0	0.0
Hartford	159	122	140	29.79	29.96	— .02	59.9	+ 2.4	90	29	70	39	10	50	35		53	48	70	5.70	+ 2.2	14	5,580	s.	36	s.	17	9	9	13	5.8	0.0	0.0
New Haven	106	117	155	29.85	29.96	— .03	59.8	+ 2.2	92	29	69	42	10	51	35		52	46	68	6.16	+ 2.5	12	6,875	ne.	28	sw.	2	12	8	11	5.4	0.0	0.0
Middle Atlantic States.							**62.4**	**+ 0.8**											**74**	**4.50**	**+ 1.0**										**5.2**		
Albany	97	102	115	29.85	29.95	— .03	58.7	— 0.2	86	29	68	37	1	49	32		53	48	70	5.42	+ 2.4	14	5,638	s.	30	s.	23	11	9	11	5.6	0.0	0.0
Binghamton	871	10	69	29.02	29.95	— .03	58.2	+ 1.2	86	31	69	36	6	48	36					3.68	+ 0.6	14	4,263	se.	34	sw.	17	7	12	12	6.2	0.0	0.0
New York	314	414	454	29.62	29.96	— .03	61.0	+ 1.7	90	29	69	42	10	53	32		53	47	65	3.81	+ 0.6	12	11,398	e.	55	nw.	5	9	6	16	6.4	0.0	0.0
Harrisburg	374	94	104	29.56	29.96	— .02	61.8	+ 0.1	92	30	71	43	11	52	31		54	49	66	5.82	+ 2.2	12	4,544	w.	36	sw.	22	4	12	15	6.8	0.0	0.0
Philadelphia	117	123	190	29.84	29.96	— .03	64.0	+ 1.8	92	30	73	44	11	55	29		57	52	71	4.53	+ 1.3	13	7,500	s.	34	e.	10	11	5	15	6.0	0.0	0.0
Reading	325	81	98	29.61	29.95	.....	62.4	.....	92	30	72	44	13	53	32		55	51	70	3.55	+ 0.2	14	5,286	se.	31	e.	10	11	5	15	6.0	0.0	0.0
Scranton	805	111	119	29.10	29.96	— .02	60.0	+ 1.2	89	31	70	40	19	50	37		56	53	81	3.33	— 0.1	14	5,132	sw.	30	e.	10	9	8	14	6.0	0.0	0.0
Atlantic City	52	37	48	29.90	29.96	— .02	59.9	+ 2.4	90	30	66	44	13	54	30		55	52	81	5.38	+ 2.4	15	5,725	sw.	28	e.	10	12	6	13	5.3	0.0	0.0
Cape May	18	13	49	29.97	29.99	.00	60.8	+ 2.2	86	30	67	46	13	55	26		56	54	82	5.36	+ 2.4	13	6,893	se.	36	ne.	10	14	4	13	5.0	0.0	0.0
Sandy Hook	22	10	57	29.94	29.96	.....	59.6	.....	84	29	67	45	10	52	30		54	51	79	3.06	.....	11	10,328	w.	56	ne.	10	12	7	12	5.3	0.0	0.0
Trenton	190	159	183	29.75	29.95	.....	62.0	.....	90	30	72	43	10	52	31		54	49	70	4.18	+ 0.7	11	8,410	sw.	44	w.	23	11	4	16	6.2	0.0	0.0
Baltimore	123	100	113	29.82	29.95	— .04	64.9	+ 0.7	93	30	73	46	11	56	30		58	53	70	5.46	+ 1.9	14	4,899	sw.	22	sw.	24	12	6	13	5.7	0.0	0.0
Washington	112	62	85	29.82	29.94	— .06	64.6	+ 0.4	92	30	74	47	11	55	31		58	54	72	5.27	+ 1.4	10	4,408	nw.	27	nw.	17	10	7	14	6.2	0.0	0.0
Lynchburg	681	153	188	29.20	29.94	— .06	65.0	— 0.9	94	30	76	43	3	54	36		58	54	74	3.64	— 0.4	15	4,813	w.	27	sw.	22	8	13	10	5.7	0.0	0.0
Norfolk	91	170	205	29.87	29.97	— .03	67.9	+ 1.7	88	30	77	49	1	58	25		61	57	75	3.63	— 0.4	10	8,633	s.	36	nw.	17	12	9	10	4.9	0.0	0.0
Richmond	144	11	52	29.80	29.95	— .04	66.1	— 1.2	91	30	77	45	13	56	30		60	57	79	5.19	+ 1.3	13	3,972	sw.	26	w.	17	7	8	16	6.6	0.0	0.0
Wytheville	2,293	49	55	27.60	29.93	— .06	60.8	— 0.6	82	31	71	39	12	51	35		55	52	78	3.83	— 0.1	18	3,928	w.	24	w.	23	9	13	9	5.3	0.0	0.0
South Atlantic States.							**70.7**	**+ 0.9**											**80**	**4.19**	**+ 0.4**										**5.8**		
Asheville	2,255	70	84	27.63	29.94	— .05	62.9	+ 0.3	82	30	73	43	3	53	32		56	53	77	3.84	+ 0.1	18	5,736	se.	31	se.	13	6	19	6	5.4	0.0	0.0
Charlotte	773	153	161	29.11	29.94	— .05	69.0	+ 0.6	89	31	79	47	13	60	24		62	60	78	6.38	+ 2.5	11	3,550	s.	25	nw.	17	7	13	11	6.1	0.0	0.0
Hatteras	11	12	50	29.96	29.97	— .04	69.0	+ 1.9	86	31	74	54	12	63	18		65	63	84	2.12	— 2.0	8	8,530	sw.	37	w.	17	10	13	8	4.8	0.0	0.0
Raleigh	376	103	110	29.55	29.94	— .05	68.7	+ 0.6	92	31	78	50	13	59	28		62	59	77	6.15	+ 1.3	13	4,661	sw.	29	sw.	20	9	4	18	6.4	0.0	0.0
Wilmington	78	81	91	29.88	29.96	— .05	70.8	+ 1.7	86	30	78	52	15	63	22		66	64	82	1.26	— 2.8	14	5,779	sw.	24	s.	20	8	14	9	5.5	0.0	0.0
Charleston	48	11	92	29.90	29.95	— .06	74.2	+ 1.8	89	25	80	60	22	68	21		68	66	79	1.69	— 1.8	8	7,147	s.	41	ne.	25	12	8	11	5.3	0.0	0.0
Columbia, S. C	351	41	57	29.56	29.94	— .06	71.5	— 0.3	89	28	80	52	22	62	27		64	61	76	4.37	+ 1.2	10	4,993	s.	34	se.	19	8	11	12	6.2	0.0	0.0
Augusta	180	62	77	29.73	29.92	— .07	72.5	+ 0.3	89	28	82	53	22	63	32		66	64	81	4.45	+ 1.2	12	3,824	s.	25	sw.	23	4	8	19	7.4	0.0	0.0
Savannah	65	150	194	29.88	29.95	— .05	74.0	+ 1.5	90	25	82	58	22	66	23		68	66	82	4.34	+ 1.3	13	7,748	s.	34	sw.	20	7	11	13	5.8	0.0	0.0
Jacksonville	43	200	245	29.90	29.95	— .05	74.8	+ 0.6	90	25	83	60	23	67	26		67	64	77	7.32	+ 3.1	16	8,076	se.	54	sw.	20	10	15	6	4.5	0.0	0.0
Greenville, S. C	1,013	113	122	28.84	29.92	.....	67.7	.....	87	28	76	47	22	59	23		62	60	82	6.61	.....	13	5,924	sw.	36	nw.	7	5	14	12	6.2	0.0	0.0
Florida Peninsula.							**77.5**	**— 0.5**											**77**	**8.17**	**+ 3.9**										**5.5**		
Key West	22	10	64	29.90	29.92	—0.05	79.2	+ 0.2	88	28	84	68	30	74	17		73	71	77	6.81	+ 3.4	11	7,231	se.	43	se.	30	14	8	9	4.5	0.0	0.0
Miami	25	71	79	29.93	29.96	.....	76.4	— 2.2	88	18	82	64	11	71	20		71	69	78	13.31	+ 6.9	16	6,030	se.	28	e.	31	7	13	11	6.1	0.0	0.0
Tampa	35	79	92	29.91	29.94	— .05	76.8	+ 0.4	92	25	85	64	22	69	25		69	66	75	4.40	+ 1.5	14	4,660	e.	26	s.	31	5	18	8	5.8	0.0	0.0
East Gulf States.							**70.4**	**— 1.8**											**78**	**5.89**	**+ 2.4**										**6.2**		
Atlanta	1,174	190	216	28.72	29.94	—0.05	67.7	— 1.8	86	4	78	47	21	59	25		61	57	74	7.20	+ 4.1	19	6,879	nw.	60	w.	7	6	2	17	6.7	0.0	0.0
Macon	370	78	87	29.53	29.92	— .07	71.3	+ 0.2	89	4	82	50	22	61	34		63	59	70	3.99	+ 1.1	14	4,007	s.	32	se.	29	8	11	12	6.0	0.0	0.0
Thomasville	273	49	58	29.64	29.93	— .06	72.7	— 1.3	89	27	82	54	22	63	28		65	62	77	8.02	+ 4.0	18	2,898	sw.	25	sw.	26	7	9	15	6.2	0.0	0.0
Pensacola	56	149	185	29.86	29.92	— .07	71.7	— 3.1	82	14	77	55	21	68	20		68	66	83	4.47	+ 1.8	15	9,517	s.	62	sw.	26	7	12	12	5.9	0.0	0.0
Anniston	741	9	57	29.15	29.93	— .06	67.2	— 1.2	87	25	78	44	21	56	33		.....	.....	.....	5.57	+ 4.5	16	3,458	s.	27	sw.	7	8	11	12	5.9	0.0	0.0
Birmingham	709	11	48	29.18	29.93	— .05	68.0	— 3.6	85	3	77	48	22	59	28		61	58	76	4.53	+ 1.5	18	4,448	s.	28	sw.	8	6	12	13	6.4	0.0	0.0
Mobile	57	125	161	29.85	29.91	— .08	72.4	— 1.2	85	15	80	56	22	65	25		66	64	80	6.04	+ 2.0	16	7,046	sw.	41	e.	25	7	8	16	6.2	0.0	0.0
Montgomery	223	100	112	29.68	29.93	— .06	70.9	— 2.6	87	17	80	51	21	62	29		63	60	75	5.11	+ 1.3	15	4,464	sw.	32	sw.	19	5	8	18	6.7	0.0	0.0
Corinth	469	6	....	.....	.....	.....	67.2	.....	86	31	70	47	2	58	33		.....	.....	.....	5.36	.....	18	.....	s.	.....	.....	.....	4	18	9	.....	.....	.....
Jackson	304	5	....	.....	.....	.....	70.4	.....	89	17	81	47	22	60	32		.....	.....	.....	5.09	.....	11	.....	se.	.....	.....	.....	9	16	6	.....	.....	.....
Meridian	375	85	93	29.51	29.90	— .08	69.0	— 2.1	86	25	78	50	22	60	29		63	60	78	6.77	+ 2.8	14	3,686	e.	39	se.	8	7	12	12	5.7	0.0	0.0
Vicksburg	247	65	74	29.62	29.89	— .08	70.0	— 2.9	86	31	79	52	21	62	25		65	62	86	5.96	+ 1.7	11	4,636	se.	35	nw.	18	3	12	16	6.7	0.0	0.0
New Orleans	51	76	84	29.84	29.89	— .08	74.0	— 0.5	89	18	81	61	22	67	24		68	66	81	7.02	+ 3.1	13	3,738	s.	25	se.	18	8	12	11	5.7	0.0	0.0
West Gulf States.							**70.4**	**— 2.5**											**79**	**5.31**	**+ 1.2**										**5.9**		
Shreveport	249	77	93	29.61	29.88	— .07	70.1	— 3.1	88	17	79	53	21	62	28		64	61	78	5.78	+ 1.6	12	4,747	s.	24	e.	29	8	12	11	5.3	0.0	0.0
Bentonville	1,303	11	44	28.52	29.88	— .05	63.1	— 3.3	83	4	72	42	21	54	29		.....	.....	.....	5.00	— 0.2	16	3,587	ne.	21	s.	4	8	9	14	6.5	0.0	0.0
Fort Smith	457	79	94	29.39	29.88	— .07	67.7	— 2.0	87	4	76	50	21	60	26		62	60	79	4.70	— 0.2	17	5,421	e.	40	nw.	20	1	14	16	7.3	0.0	0.0
Little Rock	357	139	147	29.51	29.88	— .07	67.1	— 3.3	83	31	75	50	21	59	24		61	58	77	4.67	— 0.4	16	6,159	e.	36	nw.	19	2	14	15	7.1	0.0	0.0
Brownsville	57	4	26	.....	.....	.....	80.2	.....	100	30	91	57	21	70	33		.....	.....	.....	1.97	.....	6	.....	se.	.....	.....	.....	.....	.....	.....	.....	0.0	0.0
Corpus Christi	20	69	77	29.84	29.88	— .04	75.4	— 1.1	90	28	82	60	21	69	28		70	68	83	7.48	+ 4.7	9	8,714	se.	40	n.	11	11	9	11	4.9	0.0	0.0
Dallas	512	109	117	29.32	29.86	.....	70.0	.....	87	4	78	53	21	61	29		.....	.....	.....	4.38	.....	13	6,051	s.	44	nw.	16	2	15	14	6.5	0.0	0.0
Fort Worth	670	106	114	29.14	29.84	— .07	69.8	— 3.4	88	4	79	53	8	61	28		64	51	78	3.99	— 0.2	12	6,976	nw.	37	nw.	16	8	12	11	5.9	0.0	0.0
Galveston	54	106	114	29.83	29.89	— .05	73.0	— 2.4	86	28	78	62	24	68	19		68	66	80	9.96	+ 6.7	14	7,696	se.	37	se.	3	7	14	10	5.4	0.0	0.0
Houston	138	111	121	29.72	29.86	.....	73.1	— 2.4	88	13	81	59	10	65	25		.....	.....	.....	6.14	.....	15	5,676	se.	38	nw.	24	10	11	10	5.1	0.0	0.0
Palestine	510	64	72	29.35	29.87	— .06	70.2	— 2.3	86	15	79	54	21	62	29		64	62	81	3.96	— 0.9	12	4,749	s.	27	e.	4	7	11	13	6.3	0.0	0.0
Port Arthur	34	58	66	29.82	29.86	.....	71.9	.....	84	28	79	58	21	65	21		67	65	81	9.55	.....	14	6,534	s.	45	e.	25	9	12	10	5.8	0.0	0.0
San Antonio	701	119	132	29.13	29.85	— .05	73.4	— 1.4	90	31	83	57	10	63	28		66	62	74	3.06	+ 0.1	10	5,712	se.	43	nw.	24	10	11	10	4.9	0.0	0.0
Taylor	582	55	63	29.28	29.89	— .02	71.4	— 2.9	88	18	81	55	9	62	28		.....	.....	.....	4.54	+ 0.5	11	5,911	se.	31	nw.	19	8	12	11	5.9	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, May, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Wet thermometer.	Dew-point.	Relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean	Mean	Mean	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.							
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F*		°*F*	°*F*		°*F*	°*F*	°*F*	°*F*	%	*In.*	*In.*		*Miles*									*0–10*	*In.*	*In.*
							62.6	− 2.4										73	4.87	+ 1.2											6.7		
Chattanooga	762	189	213	29.13	29.93	− .06	66.5	− 2.1	84	25	75	44	22	58	32	60	55	71	4.32	+ 0.7	19	5,591	sw.	34	sw.	19	4	12	15	6.6	0.0	0.0
Knoxville	996	102	111	28.87	29.91	− .08	68.7	+ 0.2	91	31	76	46	22	57	34	60	57	76	4.11	+ 0.4	16	4,266	sw.	23	sw.	20	5	13	13	6.7	0.0	0.0
Memphis	399	76	97	29.51	29.93	− .03	67.0	− 3.7	84	3	74	50	21	60	20	62	59	80	5.51	+ 1.2	19	5,579	s.	35	nw.	23	4	8	19	7.2	0.0	0.0
Nashville	546	168	191	29.34	29.93	− .05	66.0	− 2.8	85	30	75	48	21	58	28	59	55	75	8.67	+ 5.2	17	5,914	nw.	41	w.	19	7	11	13	6.5	0.0	0.0
Lexington	989	193	239	28.86	29.91	− .08	62.2	− 2.1	90	30	70	43	13	54	25	.....	.....	.....	6.38	+ 2.9	15	8,705	sw.	34	sw.	1	8	3	20	7.0	0.0	0.0
Louisville	525	219	255	29.34	29.92	− .06	63.4	− 3.3	90	30	72	45	21	55	28	57	53	72	4.22	+ 0.6	15	7,919	ne.	48	nw.	23	5	9	17	6.8	0.0	0.0
Evansville	431	139	175	29.45	29.92	− .05	63.8	− 3.3	91	29	72	44	21	56	24	58	54	75	4.74	+ 1.3	16	7,606	ne.	36	sw.	3	3	14	14	6.9	0.0	0.0
Indianapolis	822	194	230	29.04	29.92	− .05	59.4	− 3.9	91	30	68	41	13	51	35	53	49	72	3.31	− 0.6	12	9,086	ne.	48	w.	1	7	11	13	6.5	0.0	0.0
Terre Haute	575	96	129	29.29	29.90	.....	60.9	.....	91	30	69	44	21	52	32	55	50	71	3.61	.....	11	7,087	ne.	35	sw.	3	1	19	11	6.8	0.0	0.0
Cincinnati	628	11	51	29.21	29.92	− .07	60.1	− 3.2	88	31	69	42	12	51	31	55	50	72	3.56	0.0	14	5,394	ne.	26	sw.	1	6	8	17	6.9	0.0	0.0
Columbus	824	173	222	29.05	29.92	− .06	59.2	− 3.1	91	31	68	40	12	50	35	51	50	75	5.19	+ 1.5	12	7,960	ne.	48	nw.	1	7	11	13	6.3	0.0	0.0
Dayton	899	181	216	28.94	29.88	.....	59.0	− 3.9	92	30	68	40	18	50	33	53	48	71	4.33	+ 0.4	14	7,463	ne.	34	sw.	3	7	9	15	6.4	0.0	0.0
Pittsburgh	842	353	410	29.03	29.93	− .06	60.8	− 1.8	94	30	70	42	12	52	34	53	48	68	4.89	+ 1.6	15	7,578	nw.	34	w.	2	7	6	18	6.6	0.0	0.0
Elkins	1,940	41	50	27.91	29.94	− .06	58.8	− 0.3	92	31	70	34	19	48	43	53	49	74	3.88	− 0.1	16	3,281	nw.	20	s.	20	6	11	14	6.5	0.0	0.0
Parkersburg	638	77	84	29.29	29.94	− .05	63.0	− 0.3	93	31	73	43	13	53	37	56	51	71	5.00	+ 1.5	13	3,635	sw.	22	nw.	17	8	9	14	6.5	0.0	0.0
Lower Lake Region.							55.9	− 1.6										72	4.22	+ 1.1											5.9		
Buffalo	767	247	280	29.11	29.94	− .03	54.0	− 0.5	90	31	61	38	3	47	25	49	45	77	4.32	+ 1.2	16	11,040	sw.	60	sw.	2	9	5	17	6.4	0.0	0.0
Canton	448	10	61	29.46	29.94	.....	54.8	− 1.4	81	29	64	32	6	46	31	.....	.....	.....	3.04	+ 0.2	18	8,390	sw.	44	w.	2	12	7	12	5.4	0.0	0.0
Oswego	335	76	91	29.58	29.94	− .03	53.5	− 1.2	74	31	61	39	11	46	23	49	45	74	4.25	+ 1.4	18	6,465	w.	30	se.	1	7	7	17	6.6	0.0	0.0
Rochester	523	97	113	29.39	29.96	− .01	56.4	− 0.3	86	29	65	40	8	48	31	50	45	70	5.20	+ 2.3	16	6,075	sw.	40	sw.	2	7	10	14	6.3	0.0	0.0
Syracuse	597	97	113	29.32	29.96	− .02	56.8	− 0.5	83	29	65	38	6	48	29	.....	.....	.....	4.91	+ 1.5	16	7,557	nw.	39	nw.	5	7	12	12	6.2	0.0	0.0
Erie	714	130	166	29.16	29.92	− .06	56.0	− 1.3	88	31	64	39	13	49	28	51	46	71	4.91	+ 1.5	19	8,801	ne.	42	se.	6	9	12	10	5.7	0.0	0.0
Cleveland	762	190	201	29.11	29.93	− .05	56.4	− 2.1	80	31	63	42	5	50	26	51	47	73	4.15	+ 0.9	16	8,513	ne.	48	w.	4	9	10	12	5.7	0.0	0.0
Sandusky	629	62	103	29.24	29.92	− .06	56.4	− 2.8	81	30	63	41	18	49	30	.....	.....	.....	3.46	+ 0.2	15	8,277	ne.	37	ne.	9	8	9	14	6.0	0.0	0.0
Toledo	628	208	243	29.25	29.93	− .04	56.8	− 2.9	87	31	65	38	12	49	29	51	47	72	4.17	+ 0.9	13	9,616	ne.	48	sw.	1	11	6	14	5.6	0.0	0.0
Fort Wayne	856	113	124	29.02	29.94	.....	57.2	− 3.0	92	31	67	39	13	48	31	51	46	70	4.77	.....	9	6,804	ne.	34	s.	3	11	7	13	5.8	0.0	0.0
Detroit	730	218	245	29.15	29.94	− .03	56.6	− 1.3	88	30	65	39	12	48	26	50	46	72	3.80	+ 0.5	13	8,531	ne.	45	sw.	1	12	8	11	5.2	0.0	0.0
Upper Lake Region.							52.8	+ 0.2										71	3.15	− 0.3											4.7		
Alpena	609	13	92	29.30	29.97	.00	50.5	+ 1.0	83	30	58	31	3	43	31	46	42	74	3.49	+ 0.2	13	7,824	se.	38	se.	6	13	8	10	5.2	T.	0.0
Escanaba	612	54	60	29.33	29.99	+ .02	51.0	+ 1.0	80	29	58	34	8	44	30	46	41	73	1.91	− 1.5	10	7,171	n.	38	n.	20	20	4	7	3.1	0.0	0.0
Grand Haven	632	54	92	29.27	29.95	− .01	53.8	− 1.0	88	31	63	36	1	45	30	48	44	72	3.56	+ 0.2	9	7,271	w.	36	ne.	20	16	7	8	4.6	0.0	0.0
Grand Rapids	707	70	87	29.19	29.96	− .01	56.4	− 2.6	94	31	67	37	1	46	31	49	42	64	4.78	+ 1.4	11	4,661	e.	24	se.	4	11	10	10	5.1	0.0	0.0
Houghton	684	62	99	29.27	30.00	+ .03	51.7	+ 2.0	90	29	62	33	9	42	34	.....	.....	.....	1.54	− 1.8	9	7,218	e.	38	w.	7	13	9	9	4.6	4.2	0.0
Lansing	878	11	62	29.00	29.94	.....	54.5	− 3.4	93	31	66	35	3	43	35	49	45	74	4.29	+ 0.7	11	4,432	ne.	20	sw.	1	9	8	14	5.8	0.0	0.0
Ludington	637	60	66	29.26	29.96	.....	52.0	.....	81	31	61	35	1	43	29	46	40	66	2.24	.....	8	6,236	e.	30	nw.	17	18	5	8	3.7	0.0	0.0
Marquette	734	77	111	29.22	30.03	+ .06	50.2	+ 1.2	92	31	58	31	9	42	29	45	40	70	2.77	− 0.6	9	5,871	nw.	32	nw.	17	13	7	11	4.9	2.2	0.0
Port Huron	638	70	120	29.24	29.93	− .04	53.2	− 0.5	88	30	61	38	3	46	29	49	45	75	3.00	− 0.2	12	7,589	ne.	43	w.	2	12	6	13	5.3	0.0	0.0
Saginaw	641	48	82	29.25	29.94	.....	54.8	.....	95	31	64	37	12	45	33	49	45	71	4.11	0.0	12	6,688	ne.	32	ne.	20	13	5	13	4.8	0.0	0.0
Sault Sainte Marie	614	11	61	29.29	29.99	+ .04	52.0	+ 4.3	91	30	64	30	6	40	41	46	42	72	2.16	− 1.1	7	6,251	w.	46	nw.	7	18	6	7	3.9	0.2	0.0
Chicago	823	140	310	29.07	29.96	.00	55.2	− 1.3	83	31	61	40	5	49	28	50	46	73	3.84	+ 0.5	11	7,653	n.	29	n.	20	13	7	11	5.0	0.0	0.0
Green Bay	617	109	144	29.30	29.96	+ .01	54.6	+ 0.1	89	31	64	36	2	46	30	48	43	68	4.53	+ 1.0	10	8,059	ne.	42	ne.	21	15	6	10	5.2	0.0	0.0
Milwaukee	681	119	133	29.21	29.95	− .01	52.9	− 0.7	79	31	60	37	5	46	24	47	41	70	2.45	− 1.0	10	6,904	ne.	45	e.	3	15	7	9	4.3	0.0	0.0
Duluth	1,133	11	47	28.78	30.00	+ .04	50.5	+ 1.9	90	28	59	31	4	42	34	45	39	68	1.72	− 1.8	9	8,121	ne.	40	ne.	14	13	9	9	4.8	1.8	0.0
North Dakota.							56.3	+ 2.0										64	3.42	+ 1.0											4.0		
Moorhead	940	8	57	28.95	29.97	+ .03	57.0	+ 2.2	91	28	70	30	5	44	36	50	45	70	4.01	+ 1.1	12	6,768	se.	31	•	4	20	3	8	3.2	0.0	0.0
Bismarck	1,674	8	57	28.18	29.95	+ .03	56.0	+ 0.8	91	27	68	30	7	44	38	48	40	62	4.06	+ 1.6	13	8,453	se.	44	s.	29	13	9	9	4.5	0.5	0.0
Devils Lake	1,482	11	44	28.37	29.93	− .01	55.7	+ 3.0	94	28	67	25	5	44	34	48	41	64	3.47	+ 1.3	13	7,965	se.	42	ne.	4	15	6	10	4.5	T.	0.0
Ellendale	1,457	10	56	28.38	29.94	.....	54.6	.....	86	29	66	31	5	44	34	49	44	70	5.22	.....	14	11,183	s.	48	ne.	4	12	5	14	5.5	T.	0.0
Grand Forks	835	12	89	.....	.....	.....	56.1	.....	92	28	69	26	5	43	36	50	.....	.....	4.62	.....	12	.....	se.	34	se.	4	15	9	7	.....	0.0	0.0
Williston	1,872	41	48	27.92	29.88	− .05	56.4	+ 2.1	96	28	69	29	4	44	38	47	39	58	2.16	− 0.1	10	7,355	se.	43	nw.	14	14	12	5	4.0	T.	0.0
Upper Mississippi Valley.							59.3	− 2.7										71	3.77	− 0.4											6.1		
Minneapolis	918	10	208	28.95	29.93	.....	58.2	.....	88	29	68	34	5	49	26	.....	.....	.....	1.71	− 2.2	7	8,440	se.	41	ne.	21	9	8	14	6.0	0.0	0.0
St. Paul	837	201	236	29.06	29.97	+ .03	58.0	− 0.2	89	28	68	36	5	48	28	.....	.....	.....	2.13	− 1.5	8	8,238	se.	41	s.	31	11	14	6	5.1	0.0	0.0
La Crosse	714	11	48	29.19	29.96	+ .02	57.6	− 1.9	90	30	69	35	2	46	33	.....	.....	.....	2.34	− 1.4	10	3,032	s.	17	w.	4	8	6	17	6.1	0.0	0.0
Madison	974	70	78	28.93	29.98	+ .02	55.2	− 2.4	91	30	64	37	9	46	33	48	41	65	3.55	− 0.1	11	6,185	se.	32	n.	20	7	6	18	7.0	0.0	0.0
Wausau	1,247	4	.....	28.64	29.98	.....	53.8	.....	88	30	65	34	18	43	37	.....	.....	.....	2.25	.....	9	.....	se.	.....	.....	.....	.....	.....	.....	17	4	10	4.2	0.0	0.0
Charles City	1,015	10	49	28.89	29.96	+ .02	56.8	− 2.7	89	30	68	32	2	46	32	51	45	68	2.72	− 2.2	10	4,215	se.	23	s.	31	9	15	7	5.2	0.0	0.0
Davenport	606	71	79	29.29	29.94	− .01	58.2	− 3.3	90	30	68	39	9	49	31	52	47	71	4.85	+ 0.7	11	5,438	e.	34	nw.	6	6	12	13	6.2	0.0	0.0
Des Moines	861	84	97	29.05	29.95	+ .02	59.8	− 1.8	86	30	69	40	2	51	27	53	48	68	2.96	− 1.6	9	5,306	se.	27	se.	3	5	13	13	6.2	0.0	0.0
Dubuque	698	81	96	29.22	29.97	+ .02	57.8	− 3.0	90	30	68	37	2	48	30	51	46	69	2.79	− 1.5	12	4,353	n.	39	se.	3	7	14	10	5.7	0.0	0.0
Keokuk	614	64	78	29.27	29.94	.00	60.0	− 3.2	88	30	69	42	9	51	33	54	50	73	4.24	0.0	14	11,903	ne.	25	w.	6	6	17	8	5.9	0.0	0.0
Cairo	356	87	93	29.51	29.89	− .07	64.9	− 2.6	86	29	72	47	9	58	27	59	56	78	3.53	− 0.3	15	5,945	ne.	30	s.	3	3	9	19	7.5	0.0	0.0
Peoria	609	11	45	29.28	29.94	− .02	58.2	− 3.5	90	30	68	40	10	48	36	53	49	76	3.79	− 0.5	12	4,518	ne.	32	sw.	3	6	9	16	6.6	0.0	0.0
Springfield, Ill	644	10	91	29.23	29.91	− .04	60.5	− 3.0	88	30	70	42	10	51	31	54	50	74	3.87	− 0.6	17	5,838	ne.	26	w.	1	6	8	17	7.1	0.0	0.0
Hannibal	534	74	109	29.34	29.90	− .04	60.6	− 3.8	87	30	70	42	9	52	32	.....	.....	.....	6.36	+ 1.4	14	6,099	ne.	32	sw.	3	6	11	14	6.4	0.0	0.0
St. Louis	567	265	303	29.30	29.90	− .05	63.0	− 3.5	88	30	71	46	9	55	27	56	52	72	7.86	+ 3.6	17	8,665	ne.	40	sw.	3	6	12	13	6.4	0.0	0.0
Missouri Valley.							60.3	− 1.7										69	3.28	− 1.0											5.4		
Columbia, Mo	781	11	84	29.07	29.90	− .04	61.5	− 3.0	87	30	70	43	2	53	29	.....	.....	.....	6.21	+ 1.4	13	5,450	ne.	26	nw.	4	4	16	11	6.5	0.0	0.0
Kansas City	963	161	181	28.88	29.91	− .01	62.8	− 1.7	84	31	71	45	9	55	26	56	51	68	3.43	− 1.7	16	8,578	n.	39	n.	19	9	15	7	5.4	0.0	0.0
St. Joseph	967	11	49	28.88	29.91	.....	62.8	.....	86	30	72	43	5	53	26	55	50	68	4.69	.....	10	5,843	ne.	34	nw.	6	11	14	6	4.9	0.0	0.0
Springfield, Mo	1,324	98	104	28.51	29.90	− .03	62.0	− 2.6	81	29	70	44	21	54	28	57	54	80	4.52	− 1.0	15	7,816	ne.	31	nw.	19	8	16	7	5.0	0.0	0.0
Iola	984	11	50	28.85	29.88	− .04	63.3	− 1.2	85	30	73	42	2	53	33	.....	.....	.....	4.15	− 0.9	13	4,912	ne.	28	nw.	3	5	15	11	6.4	0.0	0.0
Topeka	983	85	101	.....	.....	.....	62.6	− 2.4	84	29	72	44	2	53	30	.....	.....	.....	2.68	− 2.2	9	7,308	e.	33	ne.	20	7	21	3	5.0	0.0	0.0
Drexel	1,299	10	54	28.52	29.90	.....	59.2	.....	86	28	70	39	5	49	30	53	48	71	5.59	.....	12	7,273	se.	31	se.	2	10	13	8	5.4	0.0	0.0
Lincoln	1,189	11	84	28.66	29.91	.00	60.7	− 2.2	87	29	70	40	7	51	27	54	48	68	3.83	− 0.4	9	6,771	se.	36	nw.	6	8	13	10	5.9	0.0	0.0
Omaha	1,105	115	122	28.76	29.93	+ .01	61.6	− 0.9	86	29	71	43	5	53	25	54	49	68	1.70	− 2.8	14	6,085	e.	31	n.	14	8	17	6	5.6	0.0	0.0
Valentine	2,598	47	54	27.23	29.94	+ .03	55.2	− 2.7	83	29	68	30	7	42	37	49	42	66	2.14	− 1.2	10	7,829	s.	39	nw.	30	12	12	7	4.2	T.	0.0
Sioux City	1,135	94	164	28.74	29.94	+ .02	59.4	− 1.4	85	28	69	39	7	50	30	53	48	70	2.52	− 1.8	8	8,530	se.	40	nw.	6	7	12	12	6.0	0.0	0.0
Huron	1,306	59	74	28.56	29.96	+ .04	57.0	− 0.3	84	29	67	35	7	46	31	51	44	66	2.52	− 0.4	10	8,401	se.	36	se.	2	13	8	10	4.9	0.0	0.0
Pierre	1,572	70	75	28.26	29.91	.00	58.4	− 0.9	86	28	70	36	7	47	33	51	45	67	2.78	+ 0.6	9	6,789	se.	36	w.	13	17	4	10	4.2	0.0	0.0
Yankton	1,238	49	57	28.62	29.93	+ .01	58.6	− 1.4	84	30	69	38	7	48	31	.....	.....	.....	2.91	− 1.0	7	5,762	se.	33	s.	2	4	18	9	6.4	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, May, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.													
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
Northern Slope.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	*°F*		° *F*	° *F*		° *F*	° *F*	° *F*	° *F*	° *F*	%	*In*	*In.*		*Miles*							*0–10*	*In.*	*In.*
							54.4	**+ 1.4**											**56**	**1.35**	**− 1.0**									**4.6**		
Billings	3,140	5	....	27.24	29.86	− .04	57.6	.....	97	28	75	28	8	40	48	47	38	....	1.22	.....	11	.....	sw.	.....	.....	.....	15	10	6	....	0.0	0.0
Havre	2,505	11	44	27.24	29.86	− .04	56.7	+ 2.6	96	28	70	30	7	43	42	47	38	60	1.25	− 0.8	12	6,331	sw.	43	sw.	29	15	12	4	4.3	0.2	0.0
Helena	4,110	87	114	25.72	29.88	− .05	54.4	− 2.8	95	28	67	24	6	42	40	42	30	45	0.96	− 1.0	7	6,813	sw.	37	sw.	29	4	11	16	6.7	T.	0.0
Kalispell	2,962	11	34	26.85	29.88	.00	51.0	0.0	86	21	63	27	6	39	42	42	32	56	1.72	− 0.3	11	4,975	nw.	26	sw.	12	7	13	11	5.8	0.5	0.0
Miles City	2,371	26	48	27.37	29.90	− .01	60.8	+ 4.1	98	29	73	30	1	49	37	51	45	64	1.79	− 0.2	10	5,463	e.	36	w.	29	14	13	4	4.3	0.3	0.0
Rapid City	3,259	50	58	26.55	29.94	+ .04	55.6	+ 1.4	87	27	68	33	6	44	38	46	37	53	1.82	− 1.1	8	7,361	se.	38	se.	29	17	10	4	4.0	T.	0.0
Cheyenne	6,088	84	101	23.95	29.84	− .01	51.2	+ 0.2	76	27	64	28	6	38	35	41	32	54	0.70	− 1.7	4	8,417	s.	47	w.	12	9	18	4	4.7	1.3	0.0
Lander	5,372	60	68	24.56	29.84	− .04	55.4	+ 3.4	88	27	71	24	6	40	44	41	27	42	0.30	− 2.6	2	4,816	sw.	48	sw.	2	13	14	4	4.5	2.2	0.0
Sheridan	3,790	10	47	26.02	29.88	.....	54.8	.....	94	29	70	28	7	39	45	45	35	54	0.81	.....	11	5,582	nw.	40	nw.	1	20	8	3	2.8	T.	0.0
Yellowstone Park	6,200	11	48	23.83	29.91	.00	46.6	− 0.8	84	28	60	17	3	33	45	37	29	58	1.29	− 0.6	13	5,510	s.	42	s.	12	9	14	8	5.1	5.7	0.0
North Platte	2,821	11	51	27.04	29.95	+ .07	58.2	− 0.8	83	24	71	37	1	45	39	50	45	69	2.33	− 0.7	5	5,273	se.	24	nw.	6	19	5	7	3.8	0.0	0.0
Middle Slope.							**61.4**	**− 1.4**											**69**	**3.04**	**− 0.8**									**5.8**		
Denver	5,292	106	113	24.65	29.84	.00	57.8	+ 1.1	82	29	70	36	31	46	35	47	39	57	0.22	− 2.3	5	5,548	s.	39	w.	15	9	17	5	5.1	0.0	0.0
Pueblo	4,685	80	86	25.22	29.84	+ .01	59.7	+ 0.2	84	30	73	39	31	46	38	48	40	58	0.38	− 1.3	5	4,563	e.	46	w.	2	8	16	7	5.5	0.0	0.0
Concordia	1,392	50	58	28.46	29.92	+ .01	61.1	− 2.6	84	29	71	42	21	52	29	55	50	71	5.68	+ 1.0	10	5,440	ne.	36	nw.	31	4	17	10	6.5	0.0	0.0
Dodge City	2,509	11	51	27.31	28.88	+ .01	61.2	− 2.3	87	3	72	40	21	51	38	55	51	75	1.56	− 1.8	10	7,175	se.	34	se.	30	13	11	7	4.6	0.0	0.0
Wichita	1,358	139	158	28.47	29.89	− .01	63.2	− 2.7	82	29	72	44	9	55	26	57	54	76	4.72	− 0.2	13	8,291	ne.	42	w.	3	9	11	11	5.9	0.0	0.0
Altus	1,410	5	....	.....	.....	.....	67.3	.....	89	3	78	48	8	57	31	.....	.....	.....	4.89	.....	12	.....	e.	.....	.....	.....	10	8	13	....	0.0	0.0
Muskogee	652	4	....	.....	.....	.....	67.6	.....	89	29	78	45	20	58	33	.....	.....	.....	2.64	.....	13	.....	e.	.....	.....	.....	7	14	10	....	0.0	0.0
Oklahoma	1,214	10	47	28.61	29.87	− .02	65.7	− 2.4	84	3	74	46	21	57	28	60	56	79	5.66	− 0.1	14	8,517	n.	37	nw.	6	5	9	17	7.0	0.0	0.0
Southern Slope.							**68.2**	**− 2.5**											**69**	**3.21**	**+ 0.5**									**4.7**		
Abilene	1,738	10	52	28.06	29.83	− .04	68.9	− 3.0	96	31	80	47	20	58	32	61	57	72	5.73	+ 2.0	13	6,484	s.	34	se.	11	10	8	13	5.6	0.0	0.0
Amarillo	3,676	10	49	26.19	29.87	+ .03	61.8	− 2.5	87	3	73	45	20	50	37	55	52	77	2.08	− 1.6	11	7,060	ne.	39	n.	13	7	18	6	5.1	0.0	0.0
Del Rio	944	64	71	28.85	29.82	− .03	75.6	− 1.3	96	31	86	55	1	65	33	.....	.....	.....	4.04	+ 1.7	8	7,228	se.	50	e.	23	14	14	3	3.8	0.0	0.0
Roswell	3,566	75	85	26.25	29.79	− .03	66.3	− 3.1	90	30	79	48	24	54	35	55	47	57	1.00	− 0.2	6	5,950	s.	44	w.	2	15	11	5	3.7	0.0	0.0
Southern Plateau.							**67.2**	**+ 1.3**											**40**	**0.78**	**+ 0.5**									**2.6**		
El Paso	3,762	110	133	26.05	29.72	− .06	72.0	− 0.1	92	30	84	48	24	60	35	52	34	32	0.14	− 0.2	3	8,543	w.	43	sw.	30	21	9	1	2.8	0.0	0.0
Santa Fe	7,013	57	66	23.18	29.76	− .05	56.0	− 0.7	76	18	68	36	24	44	30	45	37	59	3.37	+ 2.3	14	5,870	e.	41	n.	7	5	24	2	4.9	T.	0.0
Flagstaff	6,908	8	57	23.29	29.77	− .01	52.2	+ 1.5	77	27	67	28	6	37	40	40	.....	.....	1.78	.....	7	.....	w.	36	w.	1	21	9	1	....	0.0	0.0
Phoenix	1,108	76	81	28.62	29.75	− .03	76.9	+ 2.1	101	27	92	57	23	62	37	57	42	35	0.06	0.0	1	4,353	e.	24	e.	27	28	2	1	1.4	0.0	0.0
Yuma	141	9	54	29.60	29.74	− .05	77.6	+ 0.8	102	28	94	57	7	62	40	59	45	40	T.	0.0	0	4,434	s.	25	se.	20	29	2	0	0.5	0.0	0.0
Independence	3,910	11	42	25.85	29.81	− .03	68.8	+ 4.3	96	27	83	49	8	55	38	50	33	32	0.34	+ 0.2	4	4,688	nw.	29	se.	14	17	10	4	3.4	0.0	0.0
Needles	488	4	....	29.20	29.69	.....	81.5	.....	108	27	78	54	23	65	41	.....	.....	.....	T.	.....	0	.....	.....	.....	.....	.....	24	4	3	....	.....	0.0
Middle Plateau.							**61.2**	**+ 4.7**											**39**	**0.99**	**− 0.2**									**3.5**		
Reno	4,532	74	81	25.38	29.82	−0.09	60.8	+ 7.2	93	27	77	33	6	45	42	48	33	44	1.18	+ 0.4	4	5,449	w.	33	w.	18	19	11	1	2.7	0.0	0.0
Tonopah	6,090	12	20	23.98	29.78	.....	60.0	.....	84	27	71	35	31	49	31	44	27	34	1.36	0.0	6	6,802	w.	40	nw.	30	21	9	1	2.5	0.0	0.0
Winnemucca	4,344	18	56	25.53	29.86	− .05	59.4	+ 5.0	96	28	77	28	31	42	52	44	30	42	1.25	+ 0.2	5	4,629	ne.	30	sw.	28	16	11	4	3.8	0.0	0.0
Modena	5,479	10	43	24.52	29.78	− .04	58.8	+ 4.3	84	27	75	29	6	43	42	43	27	38	0.38	− 0.5	7	8,524	sw.	46	nw.	5	18	10	3	3.5	0.0	0.0
Salt Lake City	4,360	163	203	25.51	29.81	− .05	62.5	+ 4.2	90	28	74	33	31	51	32	49	37	43	1.24	− 0.7	5	5,595	nw.	40	e.	19	15	8	8	4.4	T.	0.0
Grand Junction	4,602	82	96	25.26	29.78	− .05	64.4	+ 2.8	89	26	78	39	6	59	38	47	30	35	0.54	− 0.4	6	4,639	se.	31	nw.	30	14	12	5	4.2	0.0	0.0
Northern Plateau.							**57.1**	**+ 0.2**											**48**	**0.49**	**− 1.2**									**5.2**		
Baker	3,471	48	53	26.39	29.96	.00	51.9	+ 1.2	85	21	66	26	4	38	40	42	32	54	0.19	− 1.5	3	4,829	se.	30	sw.	14	12	7	12	5.1	T.	0.0
Boise	2,739	78	86	27.07	29.90	− .04	59.3	+ 1.7	99	28	74	31	4	45	39	47	35	45	0.08	− 1.2	3	4,522	nw.	32	sw.	14	15	11	5	4.0	T.	0.0
Lewiston	757	40	48	29.14	29.95	− .01	59.6	− 1.2	92	18	73	32	4	46	42	.....	.....	.....	0.98	− 0.6	7	3,266	e.	29	nw.	2	8	8	15	6.2	0.0	0.0
Pocatello	4,477	60	68	25.38	29.84	− .05	57.2	+ 1.7	94	28	71	28	4	43	41	44	30	40	0.35	− 1.8	4	6,557	sw.	42	sw.	2	10	18	3	4.4	T.	0.0
Spokane	1,929	101	110	27.89	29.93	− .02	55.4	− 0.7	88	21	66	35	5	44	40	45	34	51	0.76	− 0.9	9	6,191	sw.	31	sw.	29	4	12	15	6.7	0.0	0.0
Walla Walla	991	57	65	28.89	29.96	.00	59.4	− 1.3	89	21	71	36	4	48	35	48	37	48	0.58	− 1.2	4	4,248	s.	32	w.	16	13	13	5	4.5	0.0	0.0
North Pacific Coast Region.							**53.7**	**− 0.2**											**72**	**2.44**	**− 0.3**									**5.6**		
North Head	211	11	56	29.82	30.05	+0.02	50.6	− 0.6	72	13	54	43	12	47	27	48	45	82	2.36	0.0	14	14,158	nw.	64	se.	26	5	14	12	6.5	0.0	0.0
North Yakima	1,071	4	....	.....	.....	.....	58.6	.....	92	21	74	32	30	43	45	.....	.....	.....	0.58	.....	4	.....	nw.	.....	.....	.....	16	10	5	....	0.0	0.0
Port Angeles	29	8	53	30.02	30.05	.....	49.3	.....	69	21	58	33	4	40	29	.....	.....	.....	0.40	− 0.9	7	5,562	nw.	32	nw.	1	10	12	8	4.9	0.0	0.0
Seattle	125	215	250	29.91	30.04	+ .03	53.6	− 1.4	73	13	62	40	5	46	29	47	41	70	2.08	− 0.2	14	7,129	s.	38	sw.	26	6	11	14	6.3	0.0	0.0
Tacoma	213	113	129	29.81	30.03	+ .01	53.6	− 0.9	75	21	62	38	4	45	32	49	45	75	2.48	− 0.1	16	5,020	sw.	27	sw.	11	4	16	11	6.5	0.0	0.0
Tatoosh Island	86	7	57	29.92	30.02	+ .01	50.2	+ 0.6	62	14	54	43	3	46	17	46	43	80	4.53	+ 0.4	18	10,959	w.	62	s.	26	11	10	10	5.1	0.0	0.0
Medford	1,425	4	....	.....	.....	.....	57.4	.....	91	21	74	32	5	41	51	.....	.....	.....	0.03	.....	3	.....	nw.	.....	.....	.....	15	8	8	....	.....	0.0
Portland, Oreg.	153	68	106	29.87	30.02	− .01	57.2	+ 0.4	82	21	67	39	3	48	34	49	42	62	1.95	− 0.4	10	4,891	nw.	23	w.	11	9	13	9	5.3	0.0	0.0
Roseburg	510	9	57	29.49	30.04	+ .01	57.0	+ 1.0	87	21	70	34	31	44	45	49	41	65	1.23	− 0.8	9	2,612	nw.	18	sw.	14	9	18	4	4.3	0.0	0.0
Middle Pacific Coast Region.							**58.8**	**+ 1.2**											**64**	**0.28**	**− 1.0**									**3.0**		
Eureka	62	73	89	29.99	30.06	+0.01	52.1	0.0	67	26	57	42	13	47	22	49	47	84	1.48	− 1.1	7	7,242	n.	39	n.	30	9	13	9	5.1	0.0	0.0
Mount Tamalpais	2,375	11	18	27.47	29.93	− .07	56.0	+ 2.3	85	27	64	38	5	48	25	47	38	57	0.15	− 1.4	1	14,899	nw.	84	nw.	8	21	7	3	3.0	0.0	0.0
Point Reyes Light	490	7	18	29.38	29.90	.....	50.8	− 0.8	60	17	54	44	23	47	12	.....	.....	.....	0.19	.....	3	19,954	nw.	83	nw.	29	11	8	12	5.5	0.0	0.0
Red Bluff	332	50	53	29.50	29.85	− .10	69.6	+ 3.1	105	27	84	48	18	56	38	56	42	42	0.03	− 1.3	1	5,076	se.	29	nw.	30	28	2	1	1.3	0.0	0.0
Sacramento	69	106	117	29.80	29.87	− .07	65.2	+ 2.3	100	27	79	43	5	51	40	55	48	61	0.01	− 1.0	1	7,196	s.	35	nw.	31	28	2	1	1.1	0.0	0.0
San Francisco	155	209	213	29.77	29.94	− .05	57.2	+ 1.7	89	27	64	48	1	50	24	51	48	77	T.	− 0.8	0	9,738	sw.	36	sw.	7	18	11	2	2.8	0.0	0.0
San Jose	141	12	110	29.81	29.96	.....	60.7	0.0	91	27	74	39	17	47	43	.....	.....	.....	0.01	− 0.7	1	5,362	nw.	27	se.	20	28	2	1	2.0	0.0	0.0
South Pacific Coast Region.							**62.7**	**+ 0.6**											**72**	**0.20**	**− 0.4**									**4.8**		
Fresno	327	89	98	29.51	29.86	−0.06	69.8	+ 1.4	98	27	84	47	17	55	39	55	43	46	0.10	− 0.5	3	7,077	nw.	36	nw.	21	22	7	2	2.1	0.0	0.0
Los Angeles	338	159	191	29.55	29.92	− .03	61.6	− 0.9	76	27	68	50	6	55	20	56	54	82	0.19	− 0.3	4	4,048	sw.	20	s.	9	4	12	15	6.4	0.0	0.0
San Diego	87	62	70	29.83	29.91	− .04	61.0	+ 0.2	68	28	65	54	11	57	12	56	54	81	0.34	− 0.1	6	4,603	sw.	19	w.	22	4	17	10	6.5	0.0	0.0
San Luis Obispo	201	32	40	29.73	29.95	− .05	58.4	+ 1.7	88	31	69	39	18	48	43	51	47	77	0.19	− 0.7	6	3,371	nw.	20	w.	9	16	7	8	4.1	0.0	0.0
West Indies.																																					
San Juan, P. R.	82	8	54	29.90	29.98	−0.01	79.6	.....	91	16	84	70	12	75	16	.....	.....	.....	2.49	− 2.3	12	10,711	e	35	ne.	6	10	18	3	4.3	0.0	0.0
Panama Canal.																																					
Balboa Heights	118	7	97	29.70	29.82	−0.02	81.2	+ 0.6	92	4	87	73	1	76	17	77	76	86	5.21	− 3.2	23	4,807	nw.	30	s.	15	0	20	11	7.2	0.0	0.0
Colon	36	30	97	29.79	29.82	− .02	82.0	+ 1.6	92	18	86	75	23	78	14	78	77	86	6.95	− 5.6	18	5,908	se.	27	ne.	23	0	8	23	8.4	0.0	0.0
Alaska.																																					
Juneau	80	11	49	.....	.....	.....	46.2	.....	63	7	55	29	2	38	30	42	37	74	4.96	.....	21	3,330	se.	18	e.	19	3	8	20	7.5	1.2	0.0

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms for which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during May, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated. 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	23	8:35 p. m.	D. N. a. m.	1.93	11:40 p. m.	12:48 a. m.	0.07	0.06	0.11	0.17	0.29	0.35	0.39	0.43	0.56	0.82	0.92	1.08	1.30	.....	.....
	25–26	9:05 p. m.	D. N. a. m.	1.82	10:29 p. m.	11:00 p. m.	0.18	0.09	0.24	0.44	0.70	1.04	1.32	1.35	.....	.....	.....	.....	.....	.....	.....
Albany, N. Y.	17	.....	.....	1.23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.76	.....	.....	.....
Alpena, Mich.	16–17	.....	.....	1.47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.29	.....	.....	.....
Amarillo, Tex.	10	.....	.....	0.43	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.37	.....	.....	.....
Anniston, Ala.	31	.....	.....	0.82	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.52	.....	.....	.....
Asheville, N. C.	6	.....	.....	0.73	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.44	.....	.....	.....
Atlanta, Ga.	6–7	10:00 a. m.	2:50 p. m.	0.94	1:45 p. m.	2:15 p. m.	0.34	0.14	0.17	0.20	0.25	0.47	0.53	.....	.....	.....	.....	.....	.....	.....	.....
		DN., p. m.	D N., a. m.	1.45	12:32 a. m.	1:18 a. m.	0.35	0.14	0.22	0.41	0.41	0.41	0.41	0.58	0.75	0.99	1.03	.....	.....	.....	.....
		3:15 p. m.	4:40 p. m.	0.82	3:18 p. m.	3:28 p. m.	0.01	0.41	0.69	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Atlantic City, N. J.	10	.....	.....	2.61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.49	.....	.....	.....
Augusta, Ga.	13	.....	.....	0.86	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.48	.....	.....	.....
Baker, Oreg.	11	.....	.....	0.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.09	.....	.....	.....
Baltimore, Md.	10	.....	.....	1.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.55	.....	.....	.....
Bentonville, Ark.	5	2:50 p. m.	5:25 p. m.	1.07	3:00 p. m.	3:57 p. m.	0.03	0.09	0.14	0.18	0.23	0.25	0.32	0.36	0.49	0.65	0.79	0.91	.....	.....	.....
Binghamton, N. Y.	17	.....	.....	0.35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.19	.....	.....	.....
Birmingham, Ala.	5	.....	.....	1.13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.51	.....	.....	.....
Bismarck, N. Dak.	3	.....	.....	1.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.24	.....	.....	.....
Block Island, R. I.	2	.....	.....	0.49	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.28	.....	.....	.....
Boise, Idaho.	29	.....	.....	0.04	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.04	.....	.....	.....
Boston, Mass.	17	.....	.....	0.40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.35	.....	.....	.....
Buffalo, N. Y.	4	.....	.....	0.47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.20	.....	.....	.....
Burlington, Vt.	22	.....	.....	1.29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.27	.....	.....	.....
Cairo, Ill.	19	.....	.....	0.58	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.32	.....	.....	.....
Canton, N. Y.	5	.....	.....	0.31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.16	.....	.....	.....
Charles City, Iowa.	31	5:27 p. m.	7:45 p. m.	0.87	6:10 p. m.	6:35 p. m.	0.08	0.16	0.35	0.46	0.63	0.69	.....	.....	.....	.....	.....	.....	.....	.....	.....
Charleston, S. C.	25	2:20 p. m.	7:25 p. m.	0.92	2:42 p. m.	3:07 p. m.	0.01	0.11	0.21	0.46	0.61	0.70	.....	.....	.....	.....	.....	.....	.....	.....	.....
Charlotte, N. C.	7	5:35 p. m.	6:15 p. m.	0.56	5:38 p. m.	5:50 p. m.	0.01	0.31	0.47	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Chattanooga, Tenn.	26	.....	.....	0.55	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.50	.....	.....	.....
Cheyenne, Wyo.	8	.....	.....	0.54	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Chicago, Ill.	3	.....	.....	1.59	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.42	.....	.....	.....
Cincinnati, Ohio.	1	.....	.....	0.43	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.35	.....	.....	.....
Cleveland, Ohio.	16	.....	.....	0.72	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.49	.....	.....	.....
Columbia, Mo.	15–16	D N., p. m.	5:05 a. m.	1.12	3:54 a. m.	4:18 a. m.	0.41	0.17	0.31	0.44	0.57	0.67	.....	.....	.....	.....	.....	.....	.....	.....	.....
	31	1:55 p. m.	3:25 p. m.	1.08	1:58 p. m.	2:25 p. m.	0.01	0.05	0.22	0.40	0.67	0.86	0.91	.....	.....	.....	.....	.....	.....	.....	.....
Columbia, S. C.	6	.....	.....	1.63	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.65	.....	.....	.....
Columbus, Ohio.	8	.....	.....	1.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.42	.....	.....	.....
Concord, N. H.	22	.....	.....	2.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	.....	.....	.....
Concordia, Kans.	[1]	7:59 p. m.	June 1. 1:00 a. m.	1.62	8:01 p. m.	9:02 p. m.	0.01	0.17	0.27	0.35	0.45	0.55	0.72	0.81	0.92	0.96	1.00	1.19	1.23	.....	.....
Corpus Christi, Tex.	5	2:57 a. m.	5:35 a. m.	0.97	3:06 a. m.	3:40 a. m.	0.01	0.12	0.26	0.34	0.42	0.56	0.74	0.79	.....	.....	.....	.....	.....	.....	.....
	11	3:29 p. m.	5:24 p. m.	1.32	3:48 p. m.	4:42 p. m.	0.09	0.12	0.23	0.29	0.40	0.50	0.61	0.74	0.79	0.96	1.03	1.18	.....	.....	.....
	24	5:35 a. m.	7:32 a. m.	.04	5:45 a. m.	6:38 a. m.	0.03	0.17	0.39	0.61	0.78	0.96	1.19	1.47	1.60	1.69	1.81	1.90	.....	.....	.....
	25	9:13 a. m.	10:32 a. m.	0.82	9:41 a. m.	10:00 a. m.	0.09	0.08	0.22	0.57	0.67	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Dallas, Texas.	11	12:12 p. m.	1:24 p. m.	0.78	12:29 p. m.	1:02 p. m.	0.01	0.14	0.28	0.40	0.51	0.56	0.66	0.75	.....	.....	.....	.....	.....	.....	.....
	16–17	11:12 p. m.	2:35 a. m.	1.68	11:12 p. m.	11:50 p. m.	0.00	0.16	0.50	0.83	1.09	1.28	1.42	1.48	1.52	.....	.....	.....	.....	.....	.....
Davenport, Iowa.	3	.....	.....	2.05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.43	.....	.....	.....
Dayton, Ohio.	6–7	D. N. p. m.	D. N. a. m.	1.15	12:26 a. m.	12:46 a. m.	0.22	0.21	0.32	0.42	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Del Rio, Tex.	23	5:25 p. m.	11:45 p. m.	3.25	5:50 p. m.	7:08 p. m.	0.09	0.08	0.23	0.34	0.48	0.65	0.83	0.88	0.91	0.97	1.26	1.71	2.45	.....	.....
Denver, Colo.	10	.....	.....	0.06	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.06	.....	.....	.....
Des Moines, Iowa.	3–4	11:50 p. m.	D. N. a. m.	1.13	12:32 a. m.	1:11 a. m.	0.06	0.19	0.38	0.54	0.58	0.60	0.78	0.89	0.93	.....	.....	.....	.....	.....	.....
Detroit, Mich.	4	.....	.....	1.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.39	.....	.....	.....
Devils Lake, N. Dak.	30	12:40 p. m.	2:00 p. m.	0.71	12:41 p. m.	1:21 p. m.	0.01	0.13	0.29	0.30	0.32	0.46	0.48	0.52	0.60	.....	.....	.....	.....	.....	.....
Dodge City, Kans.	25	.....	.....	0.39	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Drexel, Nebr.	[2]	11:45 a. m.	3:10 p. m.	1.46	11:53 a. m.	12:44 p. m.	0.04	0.06	0.11	0.22	0.35	0.49	0.57	0.66	1.01	1.12	1.22	1.29	.....	.....	.....
		7:00 p. m.	D. N. a. m.	2.90	11:22 p. m.	12:54 a. m.	0.56	0.13	0.20	0.24	0.33	0.58	0.79	1.01	1.19	1.42	1.66	1.86	1.94	2.19	.....
Dubuque, Iowa.	6	.....	.....	0.45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.22	.....	.....	.....
Duluth, Minn.	6	.....	.....	0.56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Eastport, Me.	25	.....	.....	1.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.30	.....	.....	.....
Elkins, W. Va.	20	.....	.....	0.58	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.33	.....	.....	.....
Ellendale, N. Dak.	30	.....	.....	1.18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.37	.....	.....	.....
El Paso, Tex.	24	.....	.....	0.09	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.07	.....	.....	.....
Erie, Pa.	4	.....	.....	0.31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.28	.....	.....	.....
Escanaba, Mich.	6	.....	.....	0.49	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.15	.....	.....	.....
Eureka, Calif.	18	.....	.....	0.75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.13	.....	.....	.....
Evansville, Ind.	23	.....	.....	0.69	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.45	.....	.....	.....
Flagstaff, Ariz.	23	.....	.....	0.97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Fort Smith, Ark.	19	.....	.....	0.90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.48	.....	.....	.....
Fort Wayne, Ind.	16	.....	.....	1.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.46	.....	.....	.....
Fort Worth, Tex.	11	8:21 a. m.	12:45 p. m.	0.67	11:07 a. m.	11:27 a. m.	0.01	0.15	0.37	0.49	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	6–17	10:09 p. m.	D. N. a. m.	0.71	10:29 p. m.	10:50 p. m.	0.01	0.24	0.46	0.57	0.62	0.65	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fresno, Calif.	28	.....	.....	0.04	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.04	.....	.....	.....
Galveston, Tex.	24	7:32 a. m.	1:52 p. m.	2.74	7:53 a. m.	8:47 a. m.	0.02	0.10	0.37	0.58	0.72	0.89	1.10	.....	1.60	1.71	1.13	1.95	.....	.....	.....
Grand Haven, Mich.	3	.....	.....	1.82	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.28	.....	.....	.....
Grand Junction, Colo.	10	.....	.....	0.35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.21	.....	.....	.....
Grand Rapids, Mich.	4	.....	.....	0.65	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.33	.....	.....	.....
Green Bay, Wis.	31	1:45 p. m.	2:55 p. m.	1.28	2:09 p. m.	2:43 p. m.	0.06	0.08	0.17	0.49	0.67	0.86	1.06	1.21	.....	.....	.....	.....	.....	.....	.....
Greenville, S. C.	13	.....	.....	2.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.73	.....	.....	.....
Hannibal, Mo.	6	6:22 p. m.	D. N. p. m.	0.87	6:48 p. m.	6:59 p. m.	0.01	0.22	0.46	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	26	5:37 p. m.	7:06 p. m.	1.51	5:48 p. m.	6:25 p. m.	0.01	0.16	0.38	0.56	0.85	1.04	1.30	1.45	1.49	.....	.....	.....	.....	.....	.....
Harrisburg, Pa.	21	1:36 p. m.	3:50 p. m.	1.07	2:45 p. m.	3:28 p. m.	0.16	0.05	0.11	0.16	0.20	0.25	0.39	0.55	0.68	0.81	.....	.....	.....	.....	.....
Hartford, Conn.	21–22	D. N. a. m.	8:05 a. m.	2.68	11:08 a. m.	11:33 a. m.	0.42	0.06	0.19	0.38	0.47	0.54	0.55	0.62	.....	.....	.....	.....	.....	.....	.....
Hatteras, N. C.	22	.....	.....	0.35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.35	.....	.....	.....
Havre, Mont.	29	.....	.....	0.65	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.46	.....	.....	.....
Helena, Mont.	29	.....	.....	0.26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.20	.....	.....	.....
Houghton, Mich.	22	.....	.....	0.44	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.15	.....	.....	.....
Houston, Tex.	7	12:42 p. m.	6:15 p. m.	0.89	2:12 p. m.	2:30 p. m.	0.04	0.34	0.50	0.58	0.64	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	18	9:20 p. m.	11:54 p. m.	1.12	9:44 p. m.	10:06 p. m.	0.01	0.15	0.38	0.52	0.60	0.65	.....	.....	.....	.....	.....	.....	.....	.....	.....
	24	6.41 a. m.	12:02 p. m.	1.03	7:14 a. m.	7:22 a. m.	0.02	0.41	0.54	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Huron, S. Dak.	3	.....	.....	0.45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	.....	.....	.....
Independence, Calif.	29	.....	.....	0.18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.08	.....	.....	.....
Indianapolis, Ind.	23	.....	.....	0.49	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.34	.....	.....	.....
Iola, Kans.	18	.....	.....	1.39	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.28	.....	.....	.....
Jacksonville, Fla.	9	2:55 p. m.	3:12 p. m.	0.66	2:58 p. m.	3:08 p. m.	0 02	0.28	0.63	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	25	6:50 p. m.	8:48 p. m.	0.77	7:02 p. m.	7:25 p. m.	0.07	0.05	0.17	0.32	0.46	0.51	.....	.....	.....	.....	.....	.....	.....	.....	.....
	27	6:45 p. m.	8:20 p. m.	1.81	6:45 p. m.	7:17 p. m.	0.00	0.10	0.46	0.87	1.33	1.66	1.74	1.77	.....	.....	.....	.....	.....	.....	.....
Kalispell, Mont.	28	.....	.....	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.16	.....	.....	.....
Kansas City, Mo.	18	.....	.....	0.60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.38	.....	.....	.....
Keokuk, Iowa.	6	4:55 p. m.	7:20 p. m.	0.78	5:22 p. m.	5:47 p. m.	0.01	0.19	0.37	0.50	0.63	0.68	.....	.....	.....	.....	.....	.....	.....	.....	.....

* Self-register not in use.

[1] May 31–June 1.

[2] May 31–June 1.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during May, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Key West, Fla.	14	9:01 p. m.	D. N. p. m.	1.30	9:35 p. m.	10:29 p. m.	0.09	0.10	0.15	0.18	0.24	0.37	0.69	0.83	0.93	0.98	1.07	1.10	.....	.....	.....
	28–29	5:46 p. m.	D. N. a. m.	1.79	5:58 p. m.	6:37 p. m.	0.06	0.16	0.22	0.29	0.49	0.74	0.98	1.15	1.27	.....	.....	.....	.....	.....	.....
	30	9:12 p. m.	D. N. p. m.	1.01	9:14 p. m.	9:38 p. m.	0.01	0.19	0.51	0.71	0.86	0.91	.....	.....	.....	.....	.....	.....	.....	.....	.....
	31	1:40 p. m.	2:10 p. m.	0.84	1:45 p. m.	2:01 p. m.	0.03	0.28	0.55	0.77	0.81	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Knoxville, Tenn.	7	.....	.....	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.43	.....	.....	.....
La Crosse, Wis.	6	.....	.....	0.85	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.35	.....	.....	.....
Lander, Wyo.	31	.....	.....	0.16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Lansing, Mich.	4	.....	.....	0.95	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.60	.....	.....	.....
Lewiston, Idaho.	15	.....	.....	0.23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.11	.....	.....	.....
Lexington, Ky.	7	.....	.....	1.27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.61	.....	.....	.....
Lincoln, Nebr.	31–1	.....	.....	2.87	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Little Rock, Ark.	28	.....	.....	1.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.61	.....	.....	.....
Los Angeles, Calif.	21	.....	.....	0.13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.09	.....	.....	.....
Louisville, Ky.	24	.....	.....	0.47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.44	.....	.....	.....
Ludington, Mich.	16	.....	.....	0.33	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.27	.....	.....	.....
Lynchburg, Va.	8	.....	.....	0.46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.46	.....	.....	.....
Macon, Ga.	5	.....	.....	0.73	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.54	.....	.....	.....
Madison, Wis.	31	6:30 p. m.	8:15 p. m.	1.71	6:32 p. m.	6:57 p. m.	0.01	0.20	0.54	0.89	1.30	1.60	.....	.....	.....	.....	.....	.....	.....	.....	.....
Marquette, Mich.	1–2	.....	.....	0.79	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Memphis, Tenn.	8–9	8:02 p. m.	8:50 a. m.	1.77	10:10 p. m.	10:45 p. m.	0.35	0.10	0.30	0.46	0.53	0.57	0.62	0.69	.....	.....	.....	.....	.....	.....	.....
Meridian, Miss.	8	12:50 p. m.	2:05 p. m.	1.62	12:55 p. m.	1:53 p. m.	0.02	0.14	0.42	0.71	0.85	0.89	0.99	1.04	1.17	1.35	1.49	1.59	.....	.....	.....
	24	3:50 p. m.	D. N. p. m.	0.78	4:12 p. m.	4:37 p. m.	0.02	0.17	0.33	0.42	0.52	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....
Miami, Fla.	20	3:32 p. m.	5:25 p. m.	2.28	3:40 p. m.	5:10 p. m.	0.01	0.15	0.22	0.30	0.38	0.51	0.66	0.74	0.78	0.82	0.96	1.10	1.71	2.26	.....
	28	4:28 p. m.	5:16 p. m.	0.78	4:44 p. m.	5:06 p. m.	0.06	0.15	0.28	0.52	0.68	0.72	.....	.....	.....	.....	.....	.....	.....	.....	.....
	30	D. N. a. m.	12:30 p. m.	4.60	6:36 a. m.	6:55 a. m.	0.18	0.14	0.40	0.65	0.74	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
					8:33 a. m.	9:47 a. m.	1.17	0.05	0.18	0.36	0.48	0.71	0.91	0.96	0.98	1.40	1.71	1.95	2.27	.....	.....
					11:00 a. m.	11:26 a. m.	3.66	0.27	0.34	0.49	0.59	0.73	0.75	.....	.....	.....	.....	.....	.....	.....	.....
Milwaukee, Wis.	4	.....	.....	0.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.18	.....	.....	.....
Minneapolis, Minn.	9	.....	.....	0.46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.21	.....	.....	.....
Mobile, Ala.	24	5:18 p. m.	8:45 p. m.	1.01	5:36 p. m.	5:50 p. m.	0.02	0.29	0.62	0.72	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	31	11:30 a. m.	12:35 p. m.	0.64	11:44 a. m.	11:53 a. m.	0.01	0.34	0.56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Modena, Utah.	23	.....	.....	0.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.14	.....	.....	.....
Montgomery, Ala.	27	.....	.....	1.65	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.56	.....	.....	.....
Moorehead, Minn.	30	.....	.....	0.83	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.39	.....	.....	.....
Mount Tamalpais, Calif.	17	.....	.....	0.60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.30	.....	.....	.....
Nantucket, Mass.	11	.....	.....	0.91	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.20	.....	.....	.....
Nashville, Tenn.	8	D. N. a. m.	7:30 a. m.	1.20	3:32 a. m.	3:49 a. m.	0.05	0.27	0.47	0.62	0.67	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	19	5:30 p. m.	7:30 p. m.	1.18	5:40 p. m.	6:23 p. m.	0.01	0.29	0.48	0.63	0.74	0.78	0.83	0.90	0.95	1.00	.....	.....	.....	.....	.....
New Haven, Conn.	21	.....	.....	1.97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.57	.....	.....	.....
New Orleans, La.	25–26	.....	.....	2.35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.65	.....	.....	.....
New York, N. Y.	17	.....	.....	0.60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.30	.....	.....	.....
Norfolk, Va.	25	.....	.....	0.85	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.40	.....	.....	.....
Northfield, Vt.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
North Head, Wash.	26	.....	.....	0.41	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.15	.....	.....	.....
North Platte, Nebr.	31	.....	.....	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.31	.....	.....	.....
Oklahoma, Okla.	6	5:47 p. m.	10:30 p. m.	0.95	6:17 p. m.	6:56 p. m.	0.03	0.08	0.14	0.18	0.24	0.43	0.53	0.63	0.69	.....	.....	.....	.....	.....	.....
Omaha, Nebr.	18	.....	.....	0.55	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.34	.....	.....	.....
Oswego, N. Y.	22	.....	.....	1.10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.33	.....	.....	.....
Palestine, Tex.	11	.....	.....	0.56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.54	.....	.....	.....
Parkersburg, W. Va.	5	2:17 p. m.	2:38 p. m.	0.54	2:17 p. m.	2:31 p. m.	0.00	0.12	0.38	0.51	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pensacola, Fla.	24	7:10 p. m.	9:00 p. m.	0.82	7:17 p. m.	7:30 p. m.	0.01	0.24	0.61	0.68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Peoria, Ill.	3–4	.....	.....	1.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.29	.....	.....	.....
Philadelphia, Pa.	17	.....	.....	0.94	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.57	.....	.....	.....
Phoenix, Ariz.	22	.....	.....	0.06	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.04	.....	.....	.....
Pierre, S. Dak.	30	.....	.....	0.72	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.47	.....	.....	.....
Pittsburgh, Pa.	9	.....	.....	0.90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.35	.....	.....	.....
Pocatello, Idaho.	29	.....	.....	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.09	.....	.....	.....
Point Reyes Light, Calif.	14	.....	.....	0.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.08	.....	.....	.....
Port Angeles, Wash.	26	.....	.....	0.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.05	.....	.....	.....
Port Huron, Mich.	4	.....	.....	0.48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.30	.....	.....	.....
Portland, Me.	17	.....	.....	1.04	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.48	.....	.....	.....
Portland, Oreg.	25	.....	.....	0.67	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.17	.....	.....	.....
Providence, R. I.	2	.....	.....	0.53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.30	.....	.....	.....
Pueblo, Colo.	8	.....	.....	0.16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.12	.....	.....	.....
Raleigh, N. C.	17	2:55 p. m.	4:05 p. m.	1.13	3:05 p. m.	3:26 p. m.	0.02	0.25	0.39	0.66	1.03	1.06	.....	.....	.....	.....	.....	.....	.....	.....	.....
Rapid City, S. Dak.	10	.....	.....	0.93	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.61	.....	.....	.....
Reading, Pa.	17	.....	.....	0.46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.29	.....	.....	.....
Red Bluff, Calif.	14	.....	.....	0.03	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.03	.....	.....	.....
Reno, Nev.	28	7:10 p. m.	D. n. p. m.	0.90	7:39 p. m.	8:11 p. m.	0.02	0.06	0.26	0.41	0.53	0.66	0.79	0.83	.....	.....	.....	.....	.....	.....	.....
Richmond, Va.	5–6	9:45 p. m.	D. n. a. m.	0.94	11:09 p. m.	11:23 p. m.	T.	0.36	0.59	0.64	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Rochester, N. Y.	22	.....	.....	0.78	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	.....	.....	.....
Roseburg, Oreg.	25	.....	.....	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.10	.....	.....	.....
Roswell, N. Mex.	7	.....	.....	0.42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.40	.....	.....	.....
Sacramento, Calif.	15	.....	.....	0.01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.01	.....	.....	.....
Saginaw, Mich.	16	.....	.....	1.05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.44	.....	.....	.....
St. Joseph, Mo.	2–3	8:03 p. m.	4:50 a. m.	2.06	8:33 p. m.	9:22 p. m.	0.04	0.33	0.34	0.35	0.41	0.43	0.48	0.61	0.84	1.02	1.14	.....	.....	.....	.....
	3–4	10:32 p. m.	D. n. a. m.	1.49	10:59 p. m.	11:36 p. m.	0.01	0.07	0.21	0.38	0.52	0.68	0.79	0.96	1.03	.....	.....	.....	.....	.....	.....
St. Louis, Mo.	4	4:55 p. m.	6:40 p. m.	0.58	5:39 p. m.	7:25 p. m.	0.02	0.43	0.68	0.72	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	6	9:40 p. m.	D. n. p. m.	0.81	9:59 p. m.	10:24 p. m.	T.	0.13	0.46	0.64	0.71	0.77	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Paul, Minn.	6	.....	.....	0.45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.24	.....	.....	.....
Salt Lake City, Utah.	23	.....	.....	0.43	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.43	.....	.....	.....
San Antonio, Tex.	11	9:30 a. m.	11:22 a. m.	0.93	10:16 a. m.	11:10 a. m.	0.01	0.10	0.16	0.24	0.36	0.40	0.61	0.70	0.77	0.84	0.92	.....	.....	.....	.....
	23–24	10:00 p. m.	5:00 a. m.	1.04	3:14 a. m.	3:56 a. m.	0.17	0.08	0.13	0.21	0.33	0.42	0.54	0.65	0.76	0.80	.....	.....	.....	.....	.....
San Diego, Calif.	21	.....	.....	0.26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.24	.....	.....	.....
Sandusky, Ohio.	16	.....	.....	0.65	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.38	.....	.....	.....
Sandy Hook, N. J.	23	.....	.....	0.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.29	.....	.....	.....
San Francisco, Calif.	14	.....	.....	T.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T.	.....	.....	.....
San Jose, Calif.	14	.....	.....	0.01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.01	.....	.....	.....
San Luis Obispo, Calif.	28	.....	.....	0.05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.02	.....	.....	.....
Santa Fe, N. Mex.	23	.....	.....	1.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.29	.....	.....	.....
Sault Ste. Marie, Mich.	1–2	.....	.....	0.74	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Savannah, Ga.	25	4:45 p. m.	9:30 p. m.	1.72	5:08 p. m.	5:48 p. m.	0.03	0.06	0.19	0.44	0.65	0.90	1.04	1.12	1.18	.....	.....	.....	.....	.....	.....
Scranton, Pa.	22	.....	.....	0.53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.38	.....	.....	.....
Seattle, Wash.	29	.....	.....	0.45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.23	.....	.....	.....
Sheridan, Wyo.	2	.....	.....	0.27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.10	.....	.....	.....
Shreveport, La.	7	11:50 a. m.	8:20 p. m.	1.94	2:30 p. m.	2:50 p. m.	0.72	0.07	0.31	0.44	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	12	10:00 p. m.	10:35 p. m.	0.74	10:09 p. m.	10:26 p. m.	0.03	0.15	0.32	0.66	0.71	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sioux City, Iowa.	18	.....	.....	0.78	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.64	.....	.....	.....
Spokane, Wash.	11	.....	.....	0.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.08	.....	.....	.....

* Self-register not in use.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during May, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Springfield, Ill.	4			0.52														0.37			
Springfield, Mo.	19			0.55														0.34			
Syracuse, N. Y.	22			0.78														0.32			
Tacoma, Wash.	25			0.62														0.14			
Tampa, Fla.	3	4:50 p. m.	5:55 p. m.	1.59	4:55 p. m.	5:34 p. m.	0.01	0.18	0.47	0.71	0.98	1.24	1.44	1.51	1.56						
Tatoosh Island, Wash.	26			0.60														0.20			
Taylor, Tex.	7	8:35 a. m.	6:30 p. m.	1.51	9:39 a. m.	10:03 a. m.	0.06	0.24	0.34	0.38	0.55	0.64									
Terre Haute, Ind.	23			0.39														0.35			
Thomasville, Ga.	4	5:01 p. m.	5:35 p. m.	0.90	5:07 p. m.	5:26 p. m.	0.01	0.11	0.32	0.72	0.88										
	5	7:28 a. m.	12:30 p. m.	0.95	10:44 a. m.	10:56 a. m.	0.09	0.34	0.51	0.55											
	20	3:25 p. m.	3:59 p. m.	0.56	3:35 p. m.	3:58 p. m.	0.01	0.24	0.28	0.35	0.45	0.55									
Toledo, Ohio	4–5	6:41 p. m.	D. N. a. m.	1.01	7:49 p. m.	8:06 p. m.	0.01	0.19	0.21	0.42	0.51										
Tonopah, Nev.	28			0.57														0.38			
Topeka, Kans.	15	D. N. a. m.	6:38 a. m.	1.30	5:06 a. m.	5:45 a. m.	0.09	0.10	0.20	0.25	0.43	0.49	0.65	1.00	1.60						
Trenton, N. J.	24			0.52														0.51			
Valentine, Nebr.	5			0.74														0.22			
Vicksburg, Miss.	8			1.12														0.54			
Walla Walla, Wash.	15			0.13														0.11			
Washington, D. C.	20			1.07														0.62			
Wausau, Wis.	31			0.57														0.32			
Wichita, Kans.	16	1:45 a. m.	D. N. a. m.	0.86	1:49 a. m.	2:25 a. m.	0.01	0.17	0.36	0.50	0.56	0.60	0.68	0.82	0.85						
	18–19	9:15 p. m.	D. N. a. m.	1.04	11:10 p. m.	11:40 p. m.	0.08	0.18	0.62	0.72	0.78	0.84	0.89								
Williston, N. Dak.	10			0.66														0.55			
Wilmington, N. C.	25			0.36														0.20			
Winnemucca, Nev.	28			0.66														0.38			
Wytheville, Va.	20			1.02														0.42			
Yankton, S. Dak.	18			0.74														0.66			
Yellowstone Park, Wyo.	9–10			0.52														*			

* Self-register not in use.

TABLE III.—*Data furnished by the Canadian Meteorological Service, May, 1919.*

Stations.	Altitude above mean sea level Jan. 1, 1916.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.74	29.88	−0.10	40.3	−2.6	47.7	32.8	62	28	4.03	+0.37	T.
Sydney, C. B. I.	48	29.94	29.99	+ .02	47.4	+2.2	57.7	37.2	74	30	4.80	+1.03	.....
Halifax, N. S.	88	29.87	29.98	.00	48.6	+0.2	58.3	38.8	75	28	5.65	+1.39	0.6
Yarmouth, N. S.	65	29.88	29.95	− .03	48.5	+0 9	56.5	40.6	70	31	7.76	+3.96	.....
Charlottetown, P. E. I.	38	29.93	29.97	+ .01	47.5	+0.6	55.8	39.3	73	28	3.74	+0.83	2.0
Chatham, N. B.	28	29.97	30.00	+ .05	49.8	+1.3	60.0	39.7	79	28	3.60	+0.39	.....
Father Point, Que.	20	29.95	29.97	+ .04	43.5	−0.5	51.6	35.5	64	28	2.04	−0.54	.....
Quebec, Que.	296	29.65	29.97	+ .03	51.2	+1.3	60.4	42.0	78	29	3.80	+0.72	.....
Montreal, Que.	187	29.74	29.94	.00	55.5	+0.8	64.0	46.8	83	35	4.04	+1.09	.....
Stonecliffe, Ont.	489	29.32	29.93	.00	45.7	−6.6	66.4	25.1	92	4	4.18	+1.67	.....
Ottawa, Ont.	236	29.70	29.96	+ .02	55.8	+0.9	66.0	45.5	86	32	4.53	+1.94	.....
Kingston, Ont.	285	29.63	29.94	− .02	53.9	+1.0	62.2	45.6	85	36	7.89	+5.21	.....
Toronto, Ont.	379	29.53	29.93	− .05	55.2	+2.0	64.6	45.8	92	39	5.14	+2.10	.....
Cochrane, Ont.	930	.....	.....	.....	50.6	.....	63.0	38.2	92	19	4.55	.....	6.0
White River, Ont.	1,244	28.66	29.98	+ .03	48.8	+3.1	64.6	33.1	93	2	1.93	−0.02	2.4
Port Stanley, Ont.	592	29.29	29.93	− .04	53.4	+0.3	63.3	43.5	85	31	5.30	+2.12	.....
Southampton, Ont.	656	29.23	.....	.....	50.3	−0.4	59.0	41.6	84	32	2.67	+0.23	.....
Parry Sound, Ont.	688	29.26	29.96	+ .01	50.8	−0.3	61.5	40.1	86	31	2.09	−0.84	.....
Port Arthur, Ont.	644	29.30	30.01	+ .05	49.1	+3.2	59.7	38.6	76	27	0.83	−1.32	0.5
Winnipeg, Man.	760	29.12	29.94	− .02	57.7	+6.1	71.6	43.8	95	18	1.91	−0.37	.....
Minnedosa, Man.	1,690	28.12	29.92	− .04	55.9	+7.5	70.0	41.9	92	20	1.76	+0.31	.....
Le Pas, Man.	860	.....	.....	.....	55.7	.....	69.4	42.1	87	16	0.46	.....	.....
Qu'Appelle, Sask.	2,115	27.63	29.85	− .09	55.7	+5.9	69.1	42.2	91	22	1.84	+0.19	.....
Medicine Hat, Alb.	2,144	27.51	29.74	− .15	59.5	+5.4	73.8	45.3	96	27	1.11	−0.20	.....
Moose Jaw, Sask.	1,759	.....	.....	.....	57.8	.....	73.3	42.2	99	23	0.29	.....	.....
Swift Current, Sask.	2,392	27.27	29.86	− .06	56.2	+5.5	70.7	41.8	93	28	0.84	−0.92	0.8
Calgary, Alb.	3,428	26.31	29.85	− .03	52.2	+3.2	66.4	38.0	88	20	0.95	−0.82	4.8
Banff, Alberta	4,521	25.28	29.82	− .06	46.2	−0.8	59.6	32.7	80	18	1.32	−0.72	7.9
Edmonton, Alb.	2,150	27.49	29.75	− .13	51.4	+0.6	65.4	37.5	88	19	2.85	+1.30	9.2
Prince Albert, Sask.	1,450	28.30	29.86	− .09	56.4	+8.8	71.3	41.6	95	20	0.19	−1.07	.....
Battleford, Sask.	1,592	28.08	29.80	− .12	56.0	+5.0	71.4	40.7	93	25	0.74	−0.88	.....
Kamloops, B. C.	1,262	28.67	29.88	− .01	56.0	+3.1	67.7	44.2	79	32	0.66	−0.58	.....
Victoria, B. C.	230	29.75	30.00	.00	52.1	−0.4	59.4	44.9	68	40	0.79	−0.69	.....
Barkerville, B. C.	4,180	25.61	29.92	+ .08	40.0	−5.5	50.7	29.4	66	15	3.58	+1.06	11.8
Triangle Island, B. C.	680	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Prince Rupert, B. C.	170	.....	.....	.....	45.2	.....	50.9	39.4	58	33	7.47	.....	.....
Hamilton, Ber.	151	29.94	30.10	+ .04	71.0	+1.6	75.8	66.3	79	59	2.36	−2.30	.....

SEISMOLOGY.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., July 2, 1919.]

TABLE 1.—*Noninstrumental earthquake reports, May, 1919.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		ARIZONA.								
	H. m.		° ′	° ′			*M. s.*			
23	11 05	Flagstaff	35 12	111 37	3	1	Few.	None		G. T. Herrington.
		CALIFORNIA.								
2	8 25±	Kennett	40 45	122 24	4	1			Awakened some people	Jos. F. Beattie.
2	8 30	Anderson	40 30	122 22	5	1				Assoc. Press.
		Kennett	40 45	122 24	5	1		Rumbling	Awakened many people	Jos. F. Beattie.
		Redding	40 35	122 25	5	1				Assoc. Press.
2	8 38	Kennett	40 45	122 24	3–4	1				Jos. F. Beattie.
10	7 55	Lone Pine	36 37	118 01	4	2	Few.	None	Windows rattled	G. F. Marsh.
29	20 17	Calexico	32 41	115 30	3	1	½	Rumbling		H. M. Rouse.
		ILLINOIS.								
25	9 45	McLeansboro	38 07	88 33	3	1		Rumbling		A. E. Wilson.
		Mount Carmel	38 25	87 48	4	1		do		H. W. Seine.
		Olney	38 05	88 07	4	2		do		I. T. Ratcliffe.
		Springfield	39 48	89 39	3	1			May not be seismic	Mrs. M. W. Draper.
26	13 25½	Cairo	37 00	89 10	3	3	6	None	Windows rattled	U. S. Weather Bureau.
		INDIANA.								
25	9 45	Booneville	38 04	87 16	4				Doors banged	Wm. B. Bethell.
		Evansville	37 58	87 33	3	1		Rumbling		U. S. Weather Bureau.
		Mount Vernon	37 56	87 54	4–5	2		do	Awakened people	Guy B. Green.
		New Harmony	38 08	87 56	4	1	60	do	do	C. P. Wolfe.
		Petersburg	38 31	87 15	3–4	1	50	do	Shook buildings	David D. Corre.
		Princeton	38 23	87 34	4–5	2	60	do		R. R. Marshall.
		Vincennes	38 42	87 32	4–5				Awakened many people	Edward Cress.
		Washington	38 40	87 11	4	1	5	None		Chas. C. Feagans.
		KANSAS.								
27	3 06	Wichita	37 41	97 20	4–5	1	4	Rumbling	Furniture moved	U. S. Weather Bureau.
		KENTUCKY.								
23	12 30	Hickman	36 34	89 12	3	1	60	Rumbling		R. A. Johnson.
24	13 30	do	36 34	89 12	3	1		do		Do.
25	9 45	Louisville	38 15	85 45	2–3	1	Few.	None	Noticed by people awake	Mrs. J. B. Harris.
		do	38 15	85 45	2–3	1	10	do	Awakened people	Dr. G. C. Smith.
		Taylorsville	38 02	85 21	2	1	6	Rumbling		E. S. Speed.
26	13 25	Bardwell	36 52	89 01	2	1	10	do		Oscar Bodkin.
		Hickman	36 34	89 12	3	1		do		R. A. Johnson.
28	11 30	do	36 34	89 12	2	1	30	None		Do.
		MISSOURI.								
26	13 25	New Madrid	36 35	89 32	3	1	Few.	Rumbling		Miss Josie Smith.
		TENNESSEE.								
28	13 45	Tiptonville	36 24	89 30	3	1		None		Lucille Morris.
		UTAH.								
7	23 30	Moroni	39 32	111 30	2–3	1		None	Windows rattled	B. G. Eliason.

125518—19——6

TABLE 2.—*Instrumental seismological reports, May, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see REVIEW for January, 1919, p. 59.]

Alabama. *Mobile. Spring Hill College.* Earthquake Station. Cyril Ruhlmann, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

(No earthquake recorded during May, 1919.)

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.. E: V 10, T_0 17.7; N: V 10, T_0 16.6

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 3	.....	P_E	1 01 08	3	.....	.....	.....	Very slight motion.
		eS_E	1 08 30	.....	.....	.....	.....	
		eS_N	1 08 35	.....	.....	.....	.....	
		eL_E	1 21 00	.....	.....	.....	.....	
		eL_N	1 24 23	.....	.....	.....	.....	
		M_E	1 25 44	15	20	.....	.....	
		M_N	1 26 45	.....	.....	30	.....	
		F_N	1 40 ..	.....	.....	.....	.....	
		F_E	2 07 ..	9	.....	.....	.....	
6	.....	eP_E	20 04 56	.....	.....	.....	.....	Indefinite.
		eP_N	20 06 25	.....	.....	.....	.....	Just one wave.
		L_N	20 20 00	.....	.....	.....	.....	
		L_E	20 20 32	27	.....	.....	.....	L_E well defined.
		M_E	20 23 17	20	40	.....	.....	
		M_N	20 23 26	14	.....	80	.....	
		C_N	20 24 ..	.....	.....	.....	.....	
		C_E	20 28 ..	20	.....	.....	.....	
		F_N	20 40 ..	.....	.....	.....	.....	
		F_E	20 51 ..	18	.....	.....	.....	
18	.....	P_N	9 36 51	.....	.....	.....	.....	Motion on N–S very slight. Felt by a number of people in Sitka. Shook pictures and furniture.
		P_E	9 37 00	.....	.....	.....	.....	
		M_E	9 37 12	.....	60	.....	.....	
		F_N	9 41 30	.....	.....	.....	.....	
		F_E	9 45 00	5	.....	.....	.....	
18	.....	P_N	10 24 14	.....	.....	.....	.....	Felt in Sitka.
		P_E	10 24 26	.....	.....	.....	.....	
		M_E	10 24 52	.....	540	.....	.....	
		M_N	10 24 57	.....	.....	120	.....	
		F_N	10 27 20	.....	.....	.....	.....	
		F_E	10 44 50	6	.....	.....	.....	
20	.....	eP_E	4 27 00	.....	.....	.....	.....	Nothing on N–S.
		eL_E	4 28 00	.....	.....	.....	.....	
		F_E	4 36 ..	.....	.....	.....	.....	

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.. E: V 10, T_0 14; N: V 10, T_0 18

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 3	.....	eS_N	1 14 15	.....	.....	10	.....	Nothing on E–W.
		F_N	1 42 ..	.....	.....	.....	.....	
6	.....	L_N	20 21 30	37	.....	.....	.....	P and S masked by defective record. Only a faint record on E–W.
		M_N	20 23 20	37	.....	100	.....	
		C_N	20 32 ..	12	.....	.....	.....	
		F_N	21 05 ..	.....	.....	.....	.....	

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 22	.....	.....	.....	.....	*200	*200	.....	Tremors during 24 hours preceding 15h on date given.

*Amplitude on instrument.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(See record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80-kg., astatic, horizontal pendulum.

Instrumental constants .....

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 3	.....	L_N	1 31 —	.....	.....	.....	.....	P and S not discernible. Weak and irregular on both components.
		L_E	1 35 —	.....	.....	.....	.....	
		C_N	1 36 —	.....	.....	.....	.....	
		C_E	1 42 —	.....	.....	.....	.....	
		F_E	1 50 —	.....	.....	.....	.....	
		F_N	2 00 —	.....	.....	.....	.....	
6	.....	P	20 28 —	.....	.....	.....	.....	Waves on N–S are very weak and indistinct. S? L_N? C_N?
		M_N	20 32 —	.....	.....	*1,000	.....	
		L_E	20 40 —	15	.....	.....	.....	
		M_E	20 41 —	15	*1,000	.....	.....	
		C_E	20 47 —	.....	.....	.....	.....	
		F_E	21 03 —	.....	.....	.....	.....	
		F_N	21 08 —	.....	.....	.....	.....	
31	.....	L_E	12 20 —	.....	.....	.....	.....	Distinct wavelets on E–W.
		F_E	14 04 —	.....	.....	.....	.....	

*Trace amplitude.

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

Instrumental constants.. V 110, T_0 6.4

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 1	.....	S_N?	5 59 40	.....	.....	.....	.....	
		L	6 08 30	20	.....	.....	.....	
		L	6 23 —	16	.....	.....	.....	
		F	6 30 —	.....	.....	.....	.....	
2	.....	e	2 57 30	.....	.....	.....	.....	
		L	3 02 30	18	.....	.....	.....	
		L	3 12 —	16	.....	.....	.....	
		F	3 40 —	.....	.....	.....	.....	
3	.....	P	1 05 10	.....	.....	.....	10,110	
		PR_1	1 08 52	.....	.....	.....	.....	
		PR_2	1 10 40	.....	.....	.....	.....	
		S	1 16 13	.....	.....	.....	.....	
		L	1 34 —	40	.....	.....	.....	
		L	1 42 —	20	.....	.....	.....	
		L	1 48 —	16	.....	.....	.....	
		F	3 40 —	.....	.....	.....	.....	
6	.....	eP	20 01 00	.....	.....	.....	10,720	
		S	20 12 30	.....	.....	.....	.....	
		L	20 33 30	40	.....	.....	.....	
		L	20 39 40	18	.....	.....	.....	
		L	20 49 —	20	.....	.....	.....	
		L	21 04 —	16	.....	.....	.....	
		F	22 40 —	.....	.....	.....	.....	
18	.....	eN	9 56 50	.....	.....	.....	.....	Not on E–W.
		F	10 10 10	.....	.....	.....	.....	
18	.....	e	10 42 10	.....	.....	.....	.....	
		S	10 45 07	.....	.....	.....	.....	
		L?	10 47 10	.....	.....	.....	.....	
		F	11 15 00	.....	.....	.....	.....	
20	.....	P	4 27 10	.....	.....	.....	.....	S not discernible.
		eL	4 40 35	.....	.....	.....	.....	
		F	5 15 00	.....	.....	.....	.....	
22	.....	P	12 03 26	.....	.....	.....	7,175	
		S	12 12 04	.....	.....	.....	.....	
		eL	12 24 45	.....	.....	.....	.....	
		L	12 30 30	16	.....	.....	.....	
		F	12 50 —	.....	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, May, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.								
Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.								
Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.								
Instrumental constants..			V / T_0 / e					
		E	165 / 5.4 / 0					
		N	143 / 5.2 / 0					
		Z	*80* / *3.0* / *0*					
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
May 1	.....	L_E	6 06 11	20	.....	.....	.....	Does not show on N-S.
		F	6 40 ..	.....	.....	.....	.....	
2	.....	e_E	2 36 19	.....	.....	.....	.....	Microseisms present.
		eL_E	3 02 12	18	.....	.....	.....	
		eL_N?	3 02 12	18	.....	.....	.....	
		F	3 53 ..	.....	.....	.....	.....	
			Vertical					
		eL	*3 01 54*	*24*	.....	.....	.....	
		F	*3 55* ..	.....	.....	.....	.....	
3	.....	eP	1 05 13	.....	.....	.....	.....	Heavy microseisms present.
		P_NR	1 08 57	.....	.....	.....	.....	
		S_N	1 16 13	.....	.....	.....	.....	
		S_E	1 16 16	.....	.....	.....	.....	
		eL_E	1 37 12	27	.....	.....	.....	
		eL_N	1 37 12	11	.....	.....	.....	
		M_E	1 43 10	21	*700	.....	.....	F. 4λ.
			Vertical					
		iP	*1 05 04*	.....	.....	.....	.....	
		i	*1 08 46*	.....	.....	.....	.....	
		S	*1 16 17*	.....	.....	.....	.....	
		eL	*1 36 00*	.....	.....	.....	.....	
5	.....	L_E	5 06 11 5 12 ..	27	.....	.....	.....	Does not show on N-S.
6	.....	eP_E	20 00 40	.....	.....	.....	.....	Heavy microseisms present.
		eP_N	20 00 49	.....	.....	.....	.....	
		eS	20 12 33	.....	.....	.....	.....	
		eL_E	20 33 36	27	.....	.....	.....	
		eL_N	20 34 00	22	.....	.....	.....	
		M_N	20 43 41	14	.....	*700	.....	
		M_E	20 51 ..	16	*1,800	.....	.....	F, 23λ.
18	.....	e	10 41 05	.....	.....	.....	.....	
		S	10 45 15	.....	.....	.....	.....	
		eL_E?	10 47 12	6	.....	.....	.....	
		F	11 50 ..	.....	.....	.....	.....	
20	.....	e_E	4 27 15	.....	.....	.....	.....	
		e_N	4 32 ..	.....	.....	.....	.....	
		e_E	4 32 43	.....	.....	.....	.....	
		eL	4 41 00	14	.....	.....	.....	
		F	4 47 ..	.....	.....	.....	.....	
22	.....	eP_N	12 03 18	.....	.....	.....	.....	Heavy microseisms present.
		ePE	12 03 20	.....	.....	.....	.....	
		S	12 12 01	.....	.....	.....	.....	
		eL	12 30 06	13	.....	.....	.....	F, 13λ.

* Trace amplitude.

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant..T_0 18.4. Sensitiveness 0.40 arc tilt = 1 mm.

1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
May 1	.....	L	5 46 ..	19	.....	.....	.....	
		M	6 51 12	.....	*400	.....	.....	
		C	7 00 ..	.....	.....	.....	.....	
		F	7 16 ..	.....	.....	.....	.....	
1	.....	L	21 38 ..	18	.....	.....	.....	
		M	21 56 00	.....	*400	.....	.....	
		C	22 02 ..	.....	.....	.....	.....	
		F	22 14 ..	.....	.....	.....	.....	
2	.....	P	2 15 12	19	.....	.....	.....	
		S	2 22 00	.....	.....	.....	.....	
		L	2 25 18	19	.....	.....	.....	
		M	2 34 00	20	*2,500	.....	.....	
		C	2 41 ..	20	.....	.....	.....	Tremors for several hours.

*Trace amplitude.

Hawaii. *Honolulu. Magnetic Observatory*—Contiuued.

1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
May 3	.....	P	1 01 06	20	.....	.....	.....	
		L	1 08 12	20	.....	.....	.....	
		M	1 23 00	21	*12,000	.....	.....	
		C	1 29 ..	.....	.....	.....	.....	
		F	4 20 ..	.....	.....	.....	.....	
4	.....	L	22 58 ..	20	.....	.....	.....	
		M	23 11 30	20	*100	.....	.....	
		F	23 53 ..	.....	.....	.....	.....	
6	.....	P	4 24 00	.....	.....	.....	.....	
		L?	4 27 48	20	.....	.....	.....	
		M	4 37 00	18	*400	.....	.....	
		C	4 43 ..	.....	.....	.....	.....	
		F	5 20 ..	.....	.....	.....	.....	
6	.....	P	19 50 00	20	.....	.....	.....	Pendulum swung off the paper at 20:08:06 from 20:12:48 to 20:14:36 and from 20:16:30 to 20:18:48. Apparently two shocks.
		i	19 56 30	18	.....	.....	.....	
		i	19 59 30	.....	.....	.....	.....	
		L	20 05 30	.....	.....	.....	.....	
		M	20 14 00	18	*17,000	.....	.....	
		C	21 21 ..	.....	.....	.....	.....	
		F	24 47 ..	19	.....	.....	.....	
7	.....	P	5 25 06	17	.....	.....	.....	The two phases (I) may be P and S corresponding to L, judging by the time intervals.
		i	5 32 06	20	.....	.....	.....	
		i	5 38 12	.....	.....	.....	.....	
		L	5 43 24	.....	.....	.....	.....	
		M	5 48 18	19	*4,500	.....	.....	
		C	5 58 ..	.....	.....	.....	.....	
		F	10 03 ..	20	.....	.....	.....	
8	.....	L	5 12 ..	.....	.....	.....	.....	
		M	5 15 30	20	*100	.....	.....	
		F	5 18 ..	.....	.....	.....	.....	
8	.....	P	10 21 54	20	.....	.....	.....	
		iS	10 25 42	20	.....	.....	.....	
		eL	10 30 ..	.....	.....	.....	.....	
		M	10 35 ..	18	*400	.....	.....	
		C	10 40 ..	17	.....	.....	.....	
		F	11 30 ..	20	.....	.....	.....	
8	.....	eL	18 38 ..	.....	.....	.....	.....	
		M	18 43 30	20	*200	.....	.....	
		F	18 49 ..	.....	.....	.....	.....	
8	.....	P	19 25 30	.....	.....	.....	.....	
		eL	19 30 ..	.....	.....	.....	.....	
		M	19 31 18	15	*200	.....	.....	
		C	19 40 ..	20	.....	.....	.....	
		F	21 26 ..	..	.....	.....	.....	A few isolated tremors.
16	.....	eP	1 24 54	18	.....	.....	.....	
		eL	1 38 ..	.....	.....	.....	.....	
		M	1 42 30	19	*100	.....	.....	
		F	1 54	..	.....	.....	.....	
18	.....	L	10 40 30	.....	.....	.....	.....	
		M	10 41 00	19	*100	.....	.....	
		F	10 43 ..	.....	.....	.....	.....	
19	.....	eP	4 19 12	20	.....	.....	.....	
		L	4 25 ..	.....	.....	.....	.....	
		M	4 28 06	.....	*300	.....	.....	
		C	4 31 ..	20	.....	.....	.....	
		F	4 52 17	.....	.....	.....	.....	
20	.....	P	4 33 36	.....	*200	.....	.....	Local tremors; waves irregular.
		F	4 45 ..	20	.....	.....	.....	
22	.....	eP	12 04 42	.....	.....	.....	.....	
		eL	12 08 24	.....	.....	.....	.....	
		M	12 09 54	19	*500	.....	.....	
		C	12 18 ..	.....	.....	.....	.....	
		F	12 55 ..	19	.....	.....	.....	
23	.....	eP	3 39 48	.....	.....	.....	.....	
		eL	3 47 ..	.....	.....	.....	.....	
		M	3 52 06	18	*200	.....	.....	
		F	4 00 ..	18	.....	.....	.....	
27	.....	eP	17 40 24	.....	.....	.....	.....	P is faint. L is obscured by other activity.
		eS	17 45 48	20	.....	.....	.....	
		eL	17 49 30	.....	.....	.....	.....	
		M	17 54 ..	20	*400	.....	.....	
		C	18 04 ..	17	.....	.....	.....	
		F	18 21 ..	20	.....	.....	.....	
28	.....	eP	3 22 ..	.....	.....	.....	.....	
		L	3 25 ..	.....	.....	.....	.....	
		M	3 30 ..	20	*200	.....	.....	
		F	3 54 ..	.....	.....	.....	.....	

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, May, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Illinois. *Chicago. University of Chicago.* U. S. Weather Bureau.								
Lat., 41° 47′ N., long., 87° 37′ W. Elevation, 180.1 meters.								
Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg.								
Instrumental constants..			V / T_0 / e / Sensitivity. E 150 12 20:1 1″arc tilt=26.6 mm. N 150 8 20:1 1″arc tilt=13.2 mm.					
1919. May 1	.....	S?	*H. m. s.* 5 59 40	*Sec.*	μ	μ	*km.*	
		L	6 08 55	25				
		L	6 13 00	18				
		F	7 30 ..					
2	.....	P?	2 21 14				9,310	
		S	2 31 40					
		L	2 58 00	25				
		L	3 04 ..	18				
		F	5 20 ..					
2	.....	P?	5 58 06				11,810?	
		S	6 10 20					
		L	6 32 30					F merges with long period di0turbance that continues for hours.
		L	7 06 00	18				
2	.....	eL	21 01 00					
		L	21 10 30	18				
		F	21 40 ..					
3	.....	iP	1 04 35				9,290	
		PR	1 07 54					
		S	1 15 00					
		L	1 31 42	40				
		L	1 47 00	18				Continues with same period and small amplitude for over an hour.
		L	2 02 55	18				
		F	5 20 ..					
4	.....	P	22 58·08				8,740	
		S	23 08 05					
		L	23 25 00					
		L	23 33 00	18				
5	.....	F	0 40 ..					
6	.....	S?	4 34 33					
		L?	4 55 30					
		L	5 01 ..	18				
		F	6 30 ..					
6	.....	P	19 59 20				10,725	
		S	20 10 50					
		L	20 31 ..	35				
		L	20 50 ..	18				
		F	23 40 ..					
7	.....	P	5 32 46				9,060	
		S	5 43 00					
		L	6 02 20					
		L	6 08 ..	30				
		L	6 15 ..	18				
		L	6 30 ..	16				Merges into other disturbances at 8^h.
8	.....	P?	10 19 30				12,810?	
		S	10 32 20					
		L	10 59 00	18				
		L	11 18 00	16				F lost in disturbances after 12^h.
8	.....	L?	21 21 ..					All phases uncertain.
11	.....	eL	10 58 20					
		L	11 01 ..	16				
		F	11 30 ..					
14	.....	eL	4 42 ..					
		F	5 10 ..					
18	.....	e	9 53 54					
		F	10 05 ..					
18	.....	P?	10 37 00				1,990?	
		S	10 40 22					
		L?	10 44 ..					
		F	11 30 ..					
18	.....	eL	22 44 ..					
		L	22 46 20	18				
		L	23 00 ..	16				
		F	23 20 ..					
19	.....	eL	4 45 30					
		L	4 47 30	24				
		L	4 55 ..	18				
		F	5 20 ..					
20	.....	P	4 26 23				3,080	
		S	4 31 12					
		L	4 34 30					
		L	4 36 00	16				
		F	5 50 ..					

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Illinois. *Chicago. University of Chicago*—Continued.								
1919. May 22	.....	P_E	*H. m. s.* 12 02 47	*Sec.*	μ	μ	*km.* 6,425	N–S component not working.
		S_E	12 10 46					
		L_E	12 20 42					
		L_E	12 25 ..	18				
		L_E	12 44 30	16				
		F_E	15 00 ..					
23	.....	eL	6 59 30					
		L	7 06 ..	28				
		L	7 17 ..	15				
		F	8 00 ..					
27	.....	e	17 47 24					
		L	18 05 20	24				Merges with disturbance that continues for some time.
		F	18 40 ..					
28	.....	L	3 40 ..	24				
		F	4 00 ..					
29	.....	L	11 59 ..	24				
		L	12 10 ..	15				
		F	12 30 ..					
Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.								
Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.								
Instrument: Wiechert.								
Instrumental constants..			V / T_0 / e. E 177 3.4 4:1 N 205 3.4 4:1					
(Report for May, 1919, not received.)								
Maryland.—*Cheltenham.—Magnetic Observatory.*—U. S. Coast and Geodetic Survey. George Hartnell.								
Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.								
Instruments: Two Bosch-Omori, 10 and 12 kg.								
Instrumental constants..			V / T_0. E 10 15 N 10 15					
1919. May 3	.....	P_N	*H. m. s.* 1 05 14	*Sec.*	μ	μ	*km.*	L and succeeding portions of E–W are barely discernible.
		P_E	1 05 25	4				
		S_N	1 16 14					
		S_E	1 16 19	5				
		eL_N	1 38 50					
		eL_E	1 42 00					
		M_E	1 54 00	15	10			
		M_N	1 54 37	16		80		
		C_N	2 08 ..	15				
		F_N	3 10 ..					
6	.....	eP_E	20 02 45					
		eP_N	20 03 51					
		eL_N	20 34 ..					
		eL_E	20 36 ..					
		M_N	20 50 00	20		170		
		M_E	21 01 20	16	40			
		C_E	21 11 ..	16				
		C_N	21 18 ..	17				
		F_E	21 39 ..	16				
		F_N	22 17 ..					
18	.....	P_N	10 45 12	4				Faint, near-by shock.
		P_E	10 45 16	4				
		M_E	10 45 40		30			
		M_N	10 46 02			30		
		C	10 54 ..					
20	.....	eP_N	4 36 45					Very faint; nothing on E–W.
		eL_N	4 41 ..					
		C	4 56 ..					
Massachusetts. *Cambridge. Harvard University Seismographic Station* J. B. Woodworth.								
Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.								
Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).								
Instrumental constants..			V / T_0 / e. E 80 23 0 N 50 25 4:1					
1919. May 1	.....	O?	*H. m. s.* 7 23 54	*Sec.*	μ	μ	*km* 7,280?	65°31′ of arc. First phase masked by microseisms.
		S_N?	7 43 32	6				
		eL_N?	7 56 02	40?				
		L_N	7 56 44	24				
		L_E	8 02 26	25				
		L_N	8 03 48	20				
		L_E	8 04 37	24				
		M_E?	8 07 35	20				
		F	8 38 ..					

TABLE 2.—*Instrumental seismological reports, May, 1919*—Continued.

Massachusetts. *Cambridge. Harvard University Seismographic Station*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 2	.....	*O*?....	*2 09 ..*	.....	.....	.....	10,700	Distance from eL–S
		P_N?...	2 22 19	.....	.....	.....	.....	
		S_N?...	2 34 29	12	.....	.....	.....	
		i_N....	2 36 24	7	.....	.....	.....	
		eL_N...	2 56 21	32	.....	.....	.....	
		L_N....	2 58 54	18	.....	.....	.....	
		M_N?...	3 08 ..	17	.....	.....	.....	
		F.....	4 38 ..	.....	.....	.....	.....	
3	.....	*O*?....	*0 51 33*	.....	.....	.....	10,525?	Distance from eL–P. S phases rather vaguely defined. Possibly begins with PR_1, making distance 11,790 km. and *O*:0^{h}46^m 11^s. Cf. La Paz, distance 14,260 km *O*:0^h 51^m.
		eP....	1 05 01	3	.....	.....	.....	
		i_N....	1 08 37	17	.....	.....	.....	
		i_N....	1 15 32	16	.....	.....	.....	
		S_N....	1 16 ..	.....	.....	.....	.....	
		eL_N...	1 37 44	30	.....	.....	.....	
		L_N....	1 38 01	32	.....	.....	.....	
		L_E....	1 40 15	24	.....	.....	.....	
		M_E....	1 54 ..	.....	.....	.....	.....	
		M_N....	1 55 ..	.....	.....	.....	.....	
		F.....	5 19 ..	.....	.....	.....	.....	
4	.....	L_E....	23 42 02	20	.....	.....	.....	No trace on N–S.
		L.....	23 44 32	18	.....	.....	.....	
5	.....	F.....	0 10 ..	.....	.....	.....	.....	
6	.....	L_E....	7 09 16	20	.....	.....	.....	Not trace on N–S.
		L.....	7 10 24	18	.....	.....	.....	
		F.....	7 28 37	.....	.....	.....	.....	
6	.....	*O*.....	*19 47 13*	.....	.....	.....	10,640	95°/45′ of arc.
		eP_E...	20 00 57	.....	.....	.....	.....	
		e_E....	20 02 13	6	.....	.....	.....	
		e_N....	20 02 33	6	.....	.....	.....	
		S_E....	20 12 12	12	.....	.....	.....	
		e_E....	20 16 46	15	.....	.....	.....	
		i_N....	20 20 07	24	.....	.....	.....	
		i_E....	20 20 27	20	.....	.....	.....	
		eL_N...	20 33 52	78	.....	.....	.....	
		eL_E...	20 33 54	60	.....	.....	.....	
		L.....	20 36 17	48	.....	.....	.....	
		L.....	20 37 00	9–15	.....	.....	.....	
		L.....	20 41 02	35	.....	.....	.....	
		eM_E...	20 42 54	18	.....	.....	.....	
		M_E....	20 44 46	14	.....	.....	.....	Several maxima from 20^h 56^m 02^s to 21^h 17^m 25^s with periods from 18 to 15 secs.
		C_E....	21 29 22	.....	.....	.....	.....	
		F.....	23 16 30	.....	.....	.....	.....	
7	.....	L_E....	11 05 18	20	.....	.....	.....	Indistinct on N–S. eE, 11^h.
		F.....	11 31 ..	.....	.....	.....	.....	
18	.....	*O*?....	*8 53 ..*	.....	.....	.....	.....	Distance under 2,000 km.
		e_N....	8 57 44	2	.....	.....	.....	
		e_E....	8 57 59	.....	.....	.....	.....	
		i_N....	8 58 29	6	.....	.....	.....	
		L_E....	9 01 59	10	.....	.....	.....	
		F.....	9 05 ..	.....	.....	.....	.....	
18	.....	e_E....	10 42 55	.....	.....	.....	.....	*O*? 10^h. Distance around 2,000 km. Cf. preceding.
		e_N....	10 43 19	.....	.....	.....	.....	
		L_N....	10 45 40	.....	.....	.....	.....	
		L_E?...	10 45 43	6	.....	.....	.....	
		L_E....	10 46 21	8	.....	.....	.....	
		F.....	11 35 ..	.....	.....	.....	.....	
20	.....	*O*?....	*4 31 11*	.....	.....	.....	2,805	25° 13′ of arc.
		iP_E....	4 36 49	.....	.....	.....	.....	From the west.
		iP_N....	4 36 59	.....	.....	.....	.....	From the north.
		e_E....	4 40 20	6	.....	.....	.....	*O* and distance from L–P.
		e_N....	4 41 15	.....	.....	.....	.....	
		e_N....	4 41 36	.....	.....	.....	.....	
		eL_E...	4 42 29	13	.....	.....	.....	
		eL_N...	4 42 31	12	.....	.....	.....	
		M_N....	4 45 01	.....	.....	.....	.....	
		M_E....	4 45 24	.....	.....	.....	.....	
		C_N....	4 45 31	.....	.....	.....	.....	
		F_E....	5 15 ..	.....	.....	.....	.....	
22	.....	*O*.....	*11 52 00*	.....	.....	.....	7,790	70° 16′ of arc. Changing records from 12^h 09^m to 12^h 26^m.
		P_N....	12 03 10	2	.....	.....	.....	
		S_E....	12 12 19	8	.....	.....	.....	
		eL_N...	12 26 20	20	.....	.....	.....	
		L_E....	12 30 06	18	.....	.....	.....	
		L_E....	12 33 10	22	.....	.....	.....	
		C_E....	12 43 14	10–12	.....	.....	.....	
		F?....	13 02 ..	.....	.....	.....	.....	

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

	V	T_0	ϵ
Instrumental constants..	80	7	5:1

(Report for May, 1919, not received.)

New York. Ithaca. Cornell University. Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two, Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

		V	T_0	ϵ
Instrumental constants..	E	13	22	4:1
	N	14	25	4:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 1	.....	e_E....	6 00 15	4	.....	.....	.....	
		eL_E...	6 06 25	23	.....	.....	.....	
		F_E....	6 34 —	.....	.....	.....	.....	
2	.....	eL_E...	3 01 30	20	.....	.....	.....	
		F_E....	4 00 —	.....	.....	.....	.....	
3	.....	P_E....	1 04 53	4	.....	.....	.....	
		P_N....	1 04 56	4	.....	.....	.....	
		PR_1..	1 08 12	5	.....	.....	.....	
		S_N....	1 14 49	5	.....	.....	.....	
		S_E....	1 15 09	6	.....	.....	.....	
		L_N?...	1 25 26	22	.....	.....	.....	
		L_E....	1 31 50	44	.....	.....	.....	
		F_E....	3 54 —	.....	.....	.....	.....	
4	.....	L_E....	23 44 20	17	.....	.....	.....	
5	.....	F_E....	0 03 —	.....	.....	.....	.....	
6	.....	eP_E...	20 01 49	6	.....	.....	.....	
		L.....	20 32 25	28	.....	.....	.....	
		F.....	23 05 —	.....	.....	.....	.....	
7	.....	e_E....	2 49 27	11	.....	.....	.....	
		e_E....	2 51 58	7	.....	.....	.....	
		L_E....	2 54 33	24	.....	.....	.....	
		F_E....	3 05 —	.....	.....	.....	.....	
18	.....	eP_E...	10 43 40	3	.....	.....	.....	Phases overlapping N–S not recording.
		F_E....	10 54 —	.....	.....	.....	.....	
20	.....	e_N....	4 39 17	5	.....	.....	.....	
		L_E....	4 40 13	17	.....	.....	.....	
		F_E....	5 04 —	.....	.....	.....	.....	

New York. *New York. Fordham University.* D. H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

		V	T_0	ϵ
Instrumental constants..	E	72	5.0	0
	N	72	5.0	0

(Report for May, 1919, not received.)

Panama Canal Zone. *Balboa Heights.* Isthmian Canal Commission.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 25 kg.

	V	T_0
Instrumental constants..	10	20

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 6	.....	L_N....	8 35 30	.....	.....	.....	.....	
		L_E....	8 40 30	.....	.....	.....	.....	
		M_N....	8 50 00	.....	.....	*600	.....	
		M_E....	8 56 00	.....	*900	.....	.....	
		F.....	9 28 00	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, May, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.								
Lat., 18° 09′ N.; long., 65° 27′ W. Elevation, 19.8 meters.								
Instruments: Two Bosch-Omori.								
Instrumental constants.. V: E 10, N 10; T_0: E 17, N 19								
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 2	.....	eL_E	3 04 28	18	10	.....	.....	Nothing definite on N.
		F_E	3 12 ..	18	.....	.....	.....	
3	.....	eE	1 11 39	.....	.....	.....	.....	Probably PR_1.
		eN	1 11 48	.....	.....	.....	.....	Do.
		eN	1 21 27	.....	.....	.....	.....	
		eL_E	1 43 40	.....	.....	.....	.....	
		eL_W	1 54 30	.....	.....	.....	.....	
		M_E	1 54 07	18	20	.....	.....	
		M_N	2 00 58	19	.....	30	.....	
		F_N	2 18 ..	.....	.....	.....	.....	
		F_E	3 18 ..	16	.....	.....	.....	
6	.....	eP_E	20 01 58	.....	.....	.....	.....	
		eP_N	20 02 05	.....	.....	.....	.....	
		L_E	20 40 15	40	.....	.....	.....	
		L_N	20 40 46	40	.....	.....	.....	Well defined.
		M_E	21 00 02	18	120	.....	.....	
		M_N	21 00 20	19	.....	60	.....	
		C_N	21 11 ..	19	.....	.....	.....	
		C_E	21 21 ..	16	.....	.....	.....	
		F_N	21 54 ..	19	.....	.....	.....	
		F_E	22 05 ..	16	.....	.....	.....	
23	.....	eP_E	3 18 10	13	10	.....	.....	Nothing on N.
		F_E	3 44 ..	.....	.....	.....	.....	
Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.								
Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.								
Instruments: Two Bosch-Omori, mechanical registration.								
Instrumental constants.. V: E 10, N 10; T_0: E 15, N 16								
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 2	.....	eL	3 07 ..	16	.....	.....	.....	
		F	3 20 ..	.....	.....	.....	.....	
3	.....	P	1 04 57	.....	.....	.....	9,450	
		S	1 15 30	.....	.....	.....	.....	
		eL	1 37 ..	.....	.....	.....	.....	
		L	1 54 ..	16	.....	.....	.....	
		F	2 45 ..	.....	.....	.....	.....	
6	.....	eP	20 01 20	.....	.....	.....	9,700	
		S	20 12 05	.....	.....	.....	.....	
		L	20 35 00	40	.....	.....	.....	
		L	20 41 30	16	.....	.....	.....	
		L	20 56 00	20	.....	.....	.....	
		L	21 03 00	16	.....	.....	.....	
		F	22 05 ..	.....	.....	.....	.....	
18	.....	e	10 43 35	.....	.....	.....	.....	
		F	11 00 ..	.....	.....	.....	.....	
20	.....	e	4 36 ..	.....	.....	.....	.....	
		F	4 55 ..	.....	.....	.....	.....	
22	.....	e	12 30 00	.....	.....	.....	.....	
		L	12 33 30	.....	.....	.....	.....	
		F	12 45 ..	.....	.....	.....	.....	
Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.								
Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.								
Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80k. vertical seismograph.								
Instrumental constants.. V: 120; T_0: 26								
(Report for May, 1919, not received.)								

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Canada. *Toronto. Dominion Meteorological Service.*								
Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.								
Instrument: Milne horizontal pendulum, North; in the meridian.								
Instrumental constant..18. T_0. Pillar deviation, 1 mm. swing of boom=0.45″.								
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 1	.....	eL	6 09 00	.....	.....	.....	.....	Gradual thickening.
		M	6 15 54	.....	*800	.....	.....	
		F?	6 50 18	.....	.....	.....	.....	
		i	2 33 54	.....	.....	.....	.....	
2	.....	L	2 54 42	.....	.....	.....	.....	
		eL	3 02 42	.....	.....	.....	.....	
		M	3 08 42	.....	*2200	.....	.....	
		F	4 36 54	.....	.....	.....	.....	
3	.....	eP	1 05 18	.....	.....	.....	9,520	Phases clearly marked.
		eS	1 15 54	.....	.....	.....	.....	
		i	1 22 00	.....	.....	.....	.....	
		L	1 30 00	.....	.....	.....	.....	
		iL	1 40 48	.....	.....	.....	.....	
		iL	1 46 30	.....	.....	.....	.....	
		M	1 48 48	.....	*6800	.....	.....	
		F	2 46 42	.....	.....	.....	.....	
4	.....	L	23 41 24	.....	.....	.....	.....	
		eL	23 43 00	.....	.....	.....	.....	
		M	23 44 30	.....	*200	.....	.....	
		F	23 54 12	.....	.....	.....	.....	
6	.....	L	5 05 18	.....	.....	.....	.....	
		eL	5 07 18	.....	.....	.....	.....	
		M	5 10 54	.....	*300	.....	.....	
		F?	6 01 00	.....	.....	.....	.....	
6	.....	e	20 00 00	.....	.....	.....	9,520	
		eP	20 01 24	.....	.....	.....	.....	
		P	20 02 12	.....	.....	.....	.....	
		iP	20 04 54	.....	.....	.....	.....	
		iP	20 07 24	.....	.....	.....	.....	
		S	20 12 00	.....	.....	.....	.....	
		eS	20 12 48	.....	.....	.....	.....	
		L	20 20 06	.....	.....	.....	.....	
		L	20 24 06	.....	.....	.....	.....	
		L	20 39 30	.....	.....	.....	.....	
		iL	20 43 36	.....	.....	.....	.....	
		iL	20 47 36	.....	.....	.....	.....	Well defined vibrations continue until $21^h\ 33^m$.
		iL	20 49 36	.....	.....	.....	.....	
		M	20 52 36	.....	*7800	.....	.....	
		M	21 02 54	.....	*8500	.....	.....	
		eL	21 56 00	.....	.....	.....	.....	Increase of movement.
		M	22 00 30	.....	*3500	.....	.....	
7	.....	F?	0 47 36	.....	.....	.....	.....	
7	.....	L	5 44 12	.....	*100	.....	.....	
		F	5 48 18	.....	.....	.....	.....	
7	.....	P	5 59 36	.....	.....	.....	.....	
		e	6 08 30	.....	.....	.....	.....	
		S?	6 10 30	.....	.....	.....	.....	
		eS?	6 12 54	.....	.....	.....	.....	
		e	6 16 36	.....	.....	.....	.....	
		eL	6 23 00	.....	.....	.....	.....	
		M	6 31 00	.....	*1400	.....	.....	
		eLrep.	7 25 54	.....	.....	.....	.....	
		M	7 29 06	.....	*200	.....	.....	
		F	7 46 06	.....	.....	.....	.....	
7	.....	L	10 28 18	.....	.....	.....	.....	
		M	10 33 24	.....	*50	.....	.....	
8	.....	e?	10 50 30	.....	.....	.....	.....	
		L	11 03 00	.....	.....	.....	.....	
		eL	11 04 48	.....	.....	.....	.....	
		M	11 08 42	.....	*400	.....	.....	
8	.....	M	21 11 12	.....	*50	.....	.....	
14	.....	L	4 49 18	.....	*50	.....	.....	
		F	4 55 36	.....	.....	.....	.....	
18	.....	i	12 34 30	.....	.....	.....	.....	Probably off west coast of Vancouver Island.
		eL	12 44 00	.....	.....	.....	.....	
		M	12 44 24	.....	*400	.....	.....	
		F	13 08 30	.....	.....	.....	.....	
19	.....	L?	5 01 36	.....	*50	.....	.....	

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, May, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Canada. *Toronto. Dominion Meteorological Service*—Continued.								
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 20	.....	e.....	4 29 12	.....	.....	.....	.....	
		L.....	4 38 42	.....	.....	.....	.....	
		eL.....	4 41 42	.....	.....	.....	.....	
		M.....	4 42 06	.....	*200	.....	.....	
		F.....	4 48 30	.....	.....	.....	.....	
22	.....	L.....	12 11 18	.....	.....	.....	.....	
		L.....	12 24 36	.....	.....	.....	.....	
		eL.....	12 29 06	.....	.....	.....	.....	
		M.....	12 35 24	.....	*800	.....	.....	
		F.....	13 14 12	.....	.....	.....	.....	
23	.....	L.....	7 08 36	.....	.....	.....	.....	
		M.....	7 12 00	.....	*200	.....	.....	Thickening.
		F.....	7 29 36	.....	.....	.....	.....	
27	.....	L.....	17 51 30	.....	.....	.....	.....	
		L.....	18 03 42	.....	.....	.....	.....	
		M.....	18 08 30	.....	*100	.....	.....	
		F.....	18 18 36	.....	.....	.....	.....	
29	.....	eL.....	6 29 06	.....	.....	.....	.....	Gradual thickening
		M.....	6 30 06	.....	*200	.....	.....	
		F.....	6 37 06	.....	.....	.....	.....	

* Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instruments: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant $\frac{T_0}{}$..18. Pillar deviation, 1 mm. swing of boom=0.54″.

1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 1	.....	L.....	6 25 53	.....	*100	.....	.....	
		M.....	6 30 18	.....	.....	.....	.....	
		F?.....	7 13 35	.....	.....	.....	.....	
1	.....	L.....	16 10 42	.....	.....	.....	.....	
		M.....	16 16 36	.....	*100	.....	.....	
1	.....	L.....	22 09 14	.....	.....	.....	.....	
		M.....	22 14 38	.....	*200	.....	.....	
		F.....	22 24 28	.....	.....	.....	.....	
2	.....	P.....	2 29 37	.....	.....	.....	.....	
		L.....	2 41 33	.....	.....	.....	.....	
		M.....	2 50 28	.....	*2,400	.....	.....	
		F.....	5 01 52	.....	.....	.....	.....	
2	.....	M.....	7 06 18	.....	*50	.....	.....	
3	.....	P.....	1 01 55	.....	.....	.....	7,530	
		S.....	1 10 51	.....	.....	.....	.....	
		L.....	1 24 44	.....	.....	.....	.....	
		M.....	1 30 02	.....	*3,500	.....	.....	
		F.....	4 11 51	.....	.....	.....	.....	
4	.....	L?.....	23 14 58	.....	.....	.....	.....	
		M.....	23 28 15	.....	*100	.....	.....	
		F.....	23 49 23	.....	.....	.....	.....	
6	.....	L?.....	4 49 26	.....	.....	.....	.....	
		M.....	4 54 21	.....	*300	.....	.....	
		F.....	5 06 10	.....	.....	.....	.....	
6	.....	P.....	19 56 51	.....	.....	.....	6,860	
		S.....	20 05 13	.....	.....	.....	.....	
		L.....	20 18 59	.....	.....	.....	.....	
		M.....	20 37 40	.....	*21,000	.....	.....	
7	.....	F.....	1 04 44	.....	.....	.....	.....	
7	.....	P.....	5 37 43	.....	.....	.....	4,690	
		S.....	5 43 08	.....	.....	.....	.....	
		L.....	5 52 58	.....	.....	.....	.....	
		M.....	6 02 49	.....	*1,000	.....	.....	
		$L_{rep.}$	7 40 51	.....	.....	.....	.....	
		M.....	7 44 09	.....	.....	.....	.....	
		M.....	7 49 27	.....	*200	.....	.....	
		F.....	7 52 28	.....	.....	.....	.....	
7	.....	M.....	10 07 15	.....	*200	.....	.....	Very gradual thickening.
8	.....	L.....	10 47 38	.....	.....	.....	.....	
		M.....	10 52 33	.....	*500	.....	.....	
		F.....	11 00 26	.....	.....	.....	.....	

* Trace amplitude.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Canada. *Victoria, B. C. Dominion Meteorological Service*—Contd.								
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 8	.....	M.....	21 06 53	.....	*200	.....	.....	
		F.....	21 13 46	.....	.....	.....	.....	
14	.....	M.....	4 35 06	.....	*100	.....	.....	
18	.....	P.....	10 28 47	.....	.....	.....	270	Probably off west coast of Vancouver Island.
		L.....	10 29 17	.....	.....	.....	.....	
		M.....	10 30 16	.....	*100	.....	.....	
		F.....	10 39 07	.....	.....	.....	.....	
			Vertical					
		P.....	*10 28 44*	*2*	.....	.....	*360*	
		L.....	*10 29 24*	*3*	.....	.....	.....	
		M.....	*10 30 24*	*5*	*7*	.....	.....	
		F.....	*10 34 08*	.....	.....	.....	.....	
19	.....	L.....	4 32 49	.....	.....	.....	.....	
		M.....	4 41 40	.....	*500	.....	.....	
		F.....	4 52 29	.....	.....	.....	.....	
19	.....	M.....	23 38 45	.....	*200	.....	.....	
20	.....	P.....	4 21 35	.....	.....	.....	550	
		L.....	4 22 34	.....	.....	.....	.....	
		M.....	4 23 33	.....	*1,500	.....	.....	
		F.....	4 39 46	.....	.....	.....	.....	
			Vertical					
		L.....	*4 22 30*	*16*	.....	.....	.....	
		M.....	*4 23 34*	*14*	*6*	.....	.....	
22	.....	L.....	12 04 54	.....	.....	.....	.....	
		M.....	12 07 21	.....	*300	.....	.....	
		F.....	13 05 23	.....	.....	.....	.....	
23	.....	P.....	7 06 23	.....	.....	.....	.....	
		M.....	7 17 42	.....	*250	.....	.....	
		F.....	7 29 00	.....	.....	.....	.....	No further record until the 30th, supply of paper exhausted.

* Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

Redding, Calif., May 2, 1919.

An earthquake of 15 seconds duration was felt here early to-day and also at Anderson, Calif. No damage was reported. (Assoc. Press.)

Laspalmas, Canary Islands, May 13, 1919.

Four people were killed in the earthquake which shook the island of Fuertaventura several days ago. The bulk of the population of the island has fled. Relief measures have been undertaken. (Assoc. Press.)

Flagstaff, Ariz., May 23, 1919.

A light earthquake shock at 5:05 o'clock this morning, following a night of rain, thunder, lightning, and snow roused the city from its slumbers but caused no material damage. The home of C. O. Lampland, astronomer at Lowell Observatory, was badly shaken. (Assoc. Press.)

Tokyo, Japan, May 24, 1919.

Sixteen thousand persons were killed or injured by a volcanic eruption in central Java on May 20. This information is contained in official advices from Batavia. (Assoc. Press.)

Vincennes, Ind., May 25, 1919.

Earthquake shocks lasting two minutes were felt here and at other places in southern Indiana and Illinois and western Kentucky to-day. Many persons were awakened by the tremors, but late to-night no reports of damage had been received. (Assoc. Press.)

Amsterdam, May 26, 1919.

The volcano of Kalut in Java has burst into eruption, wiping out 20 villages in the district of Brengat and 11 in the vicinity of Blitar, and causing deaths estimated at 15,000, according to a Central News dispatch received here. (Assoc. Press.)

[1] Reported by the organization indicated and collected by the seismological station, Georgetown University, Washington, D. C.

Chart I. Hydrographs of Several Principal Rivers, May, 1919.

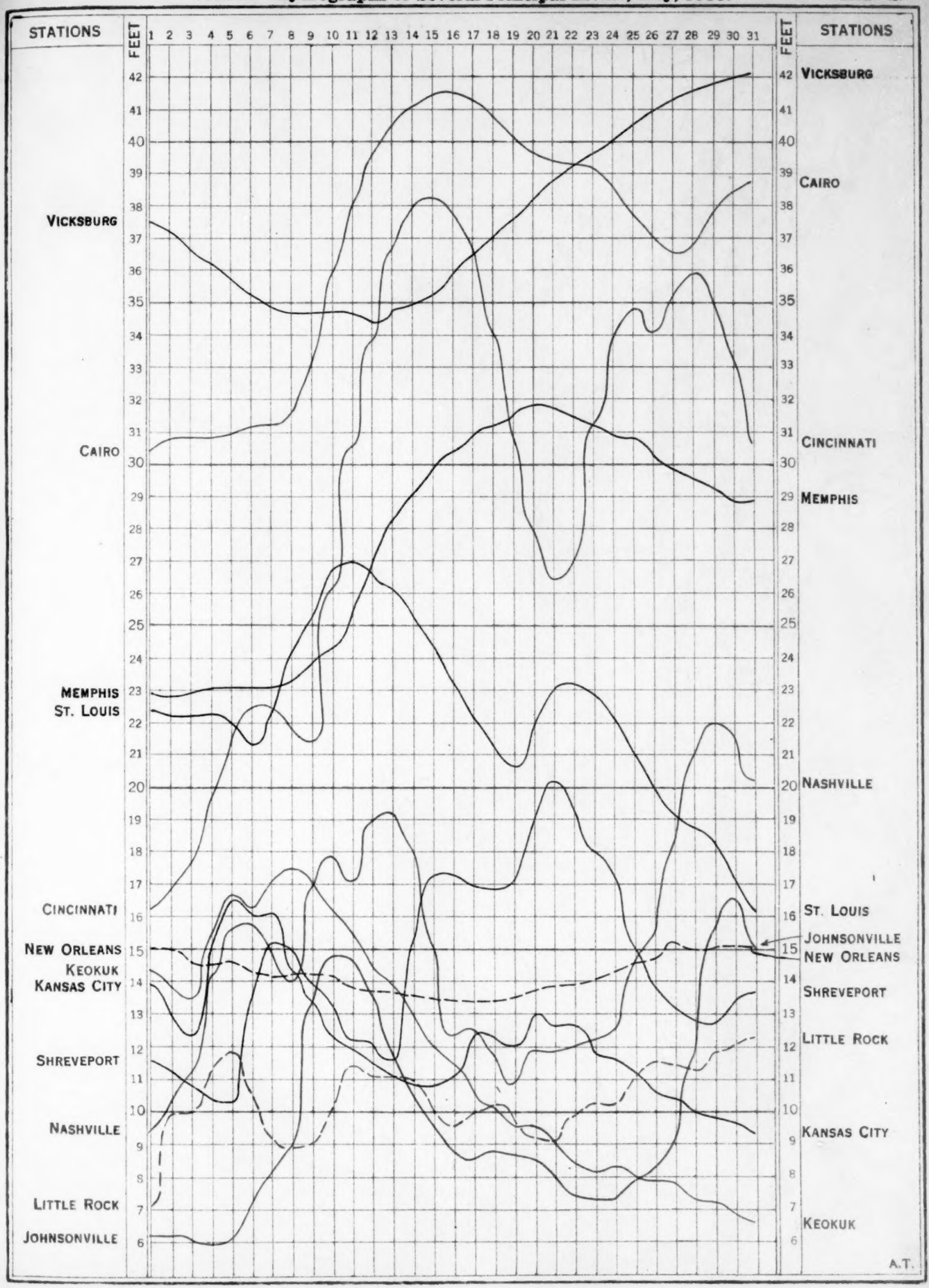


Chart II. Tracks of Centers of High Areas, May, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

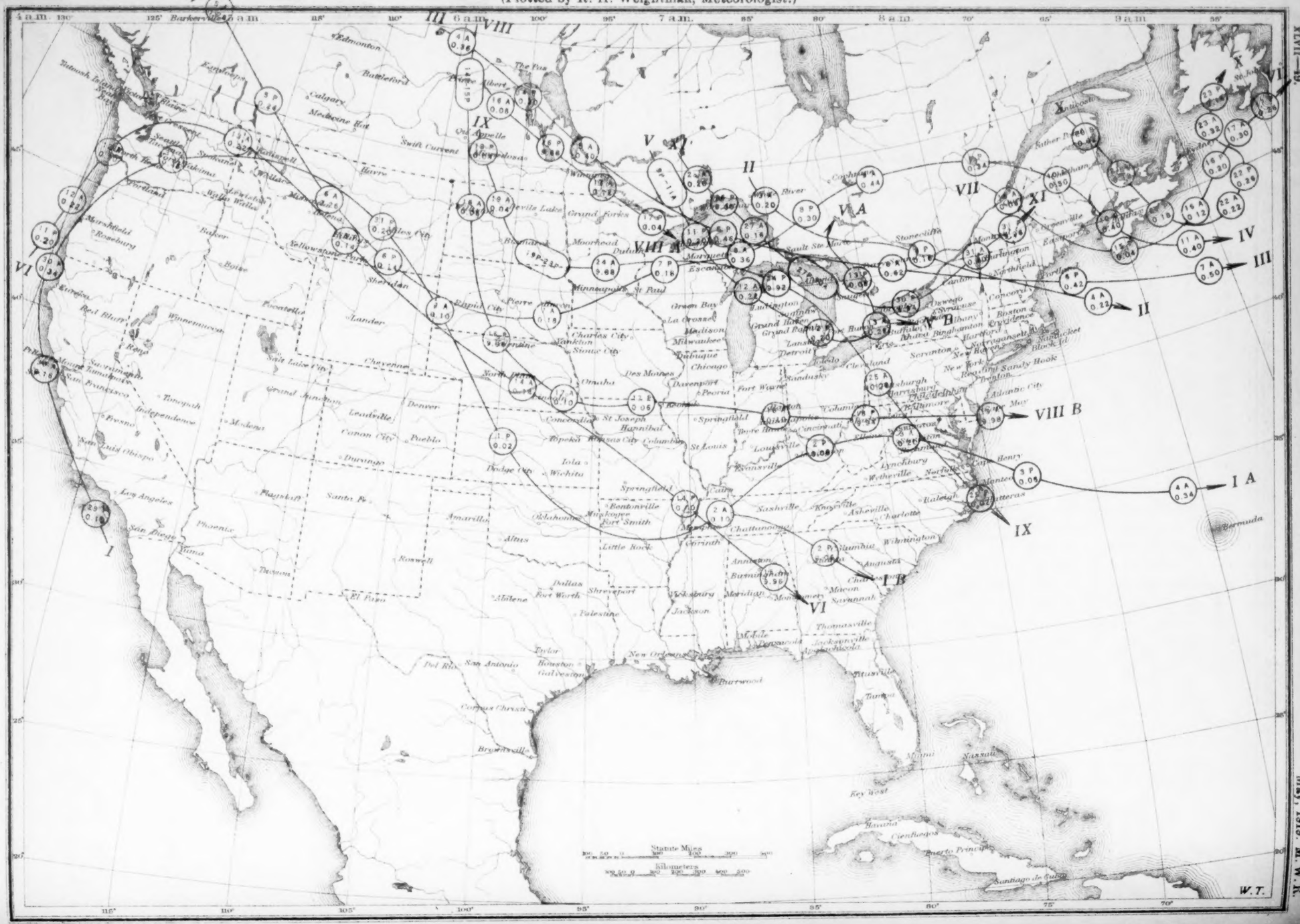


Chart III. Tracks of Centers of Low Areas, May, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

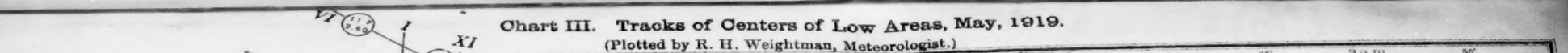


Chart III. Tracks of Centers of Low Areas, May, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

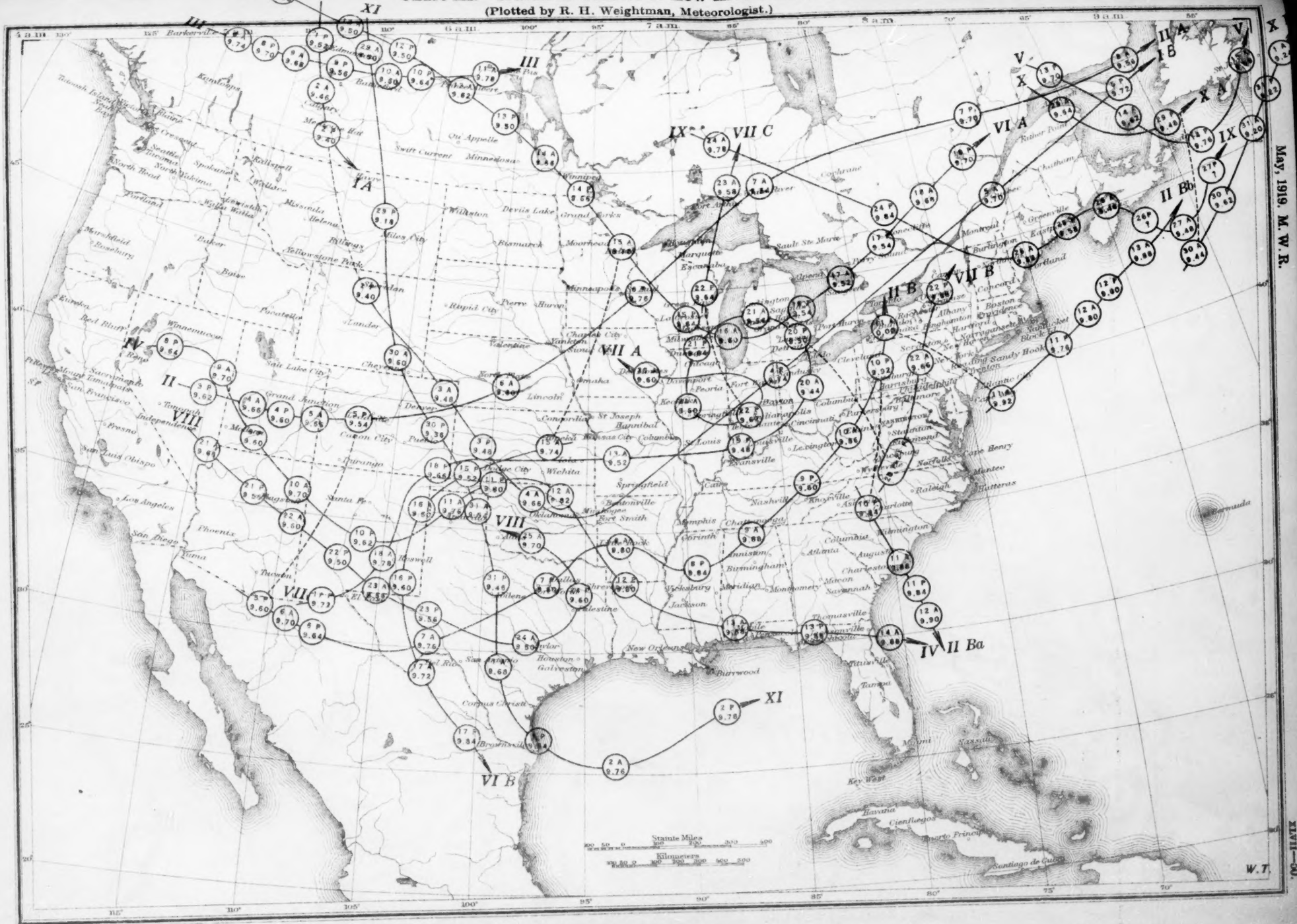


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, May, 1919.

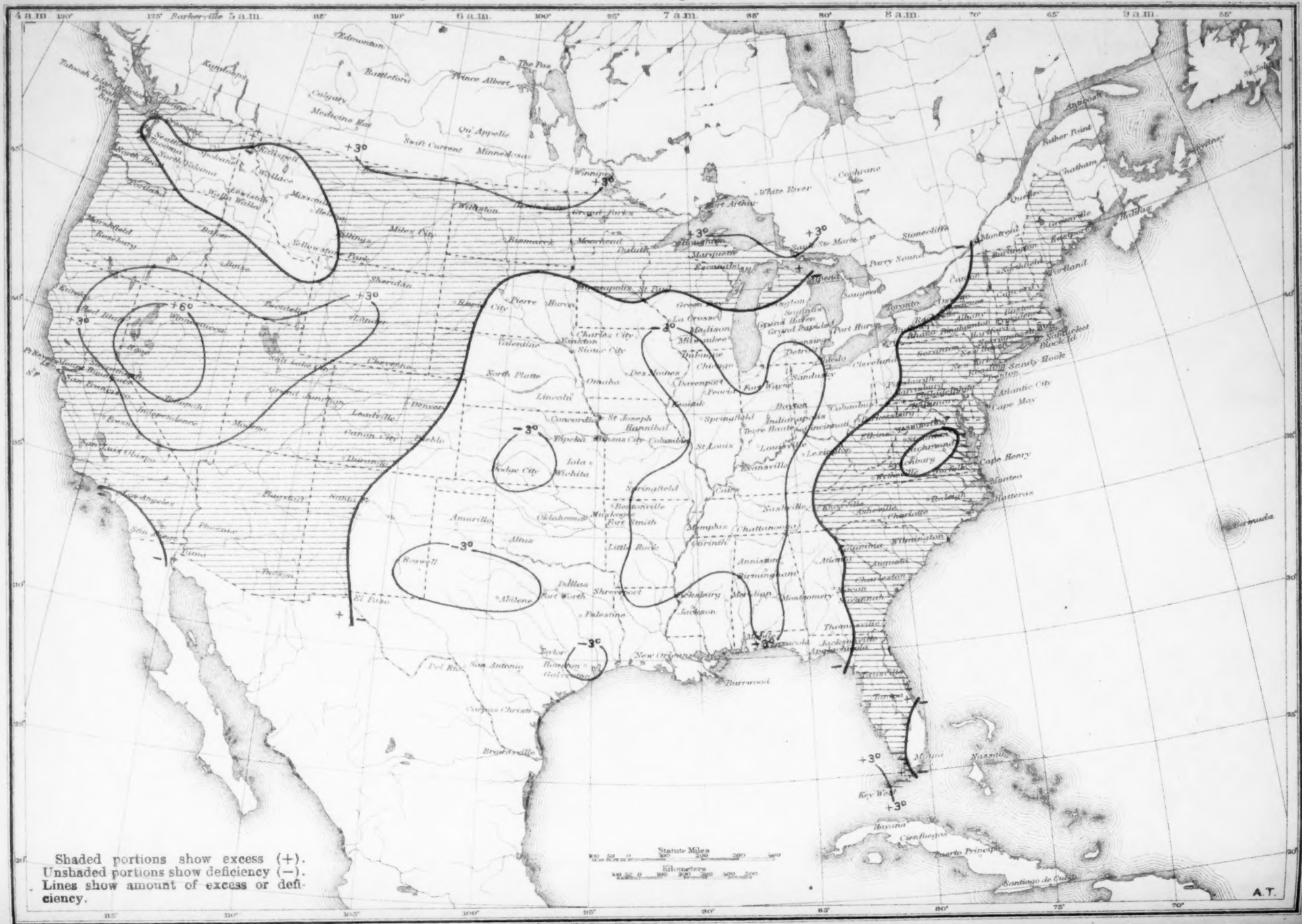


Chart V. Total Precipitation, Inches, May, 1919.

Chart V. Total Precipitation, Inches, May, 1919.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, May, 1919.

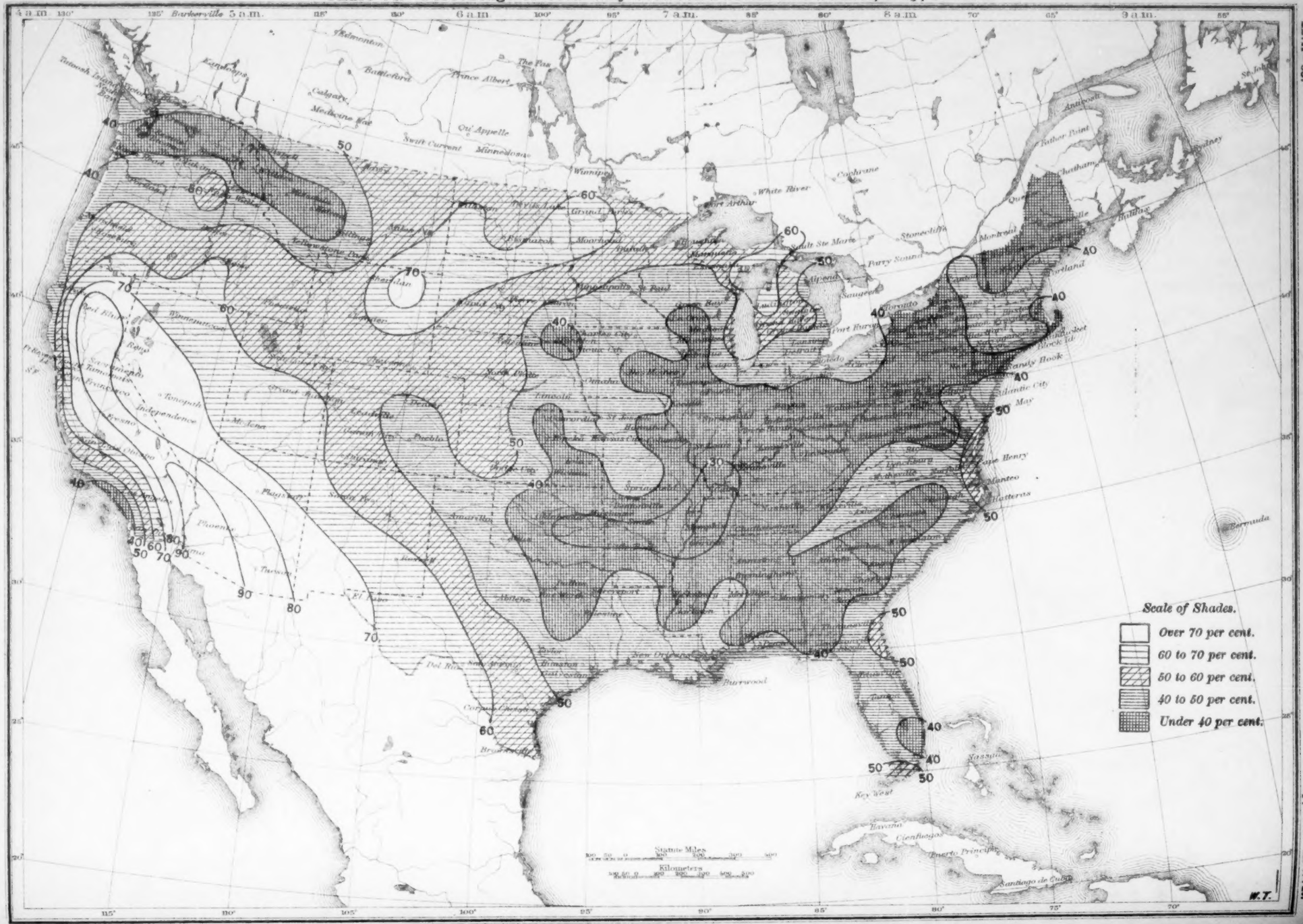


Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, May, 1919.

Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, May, 1919.

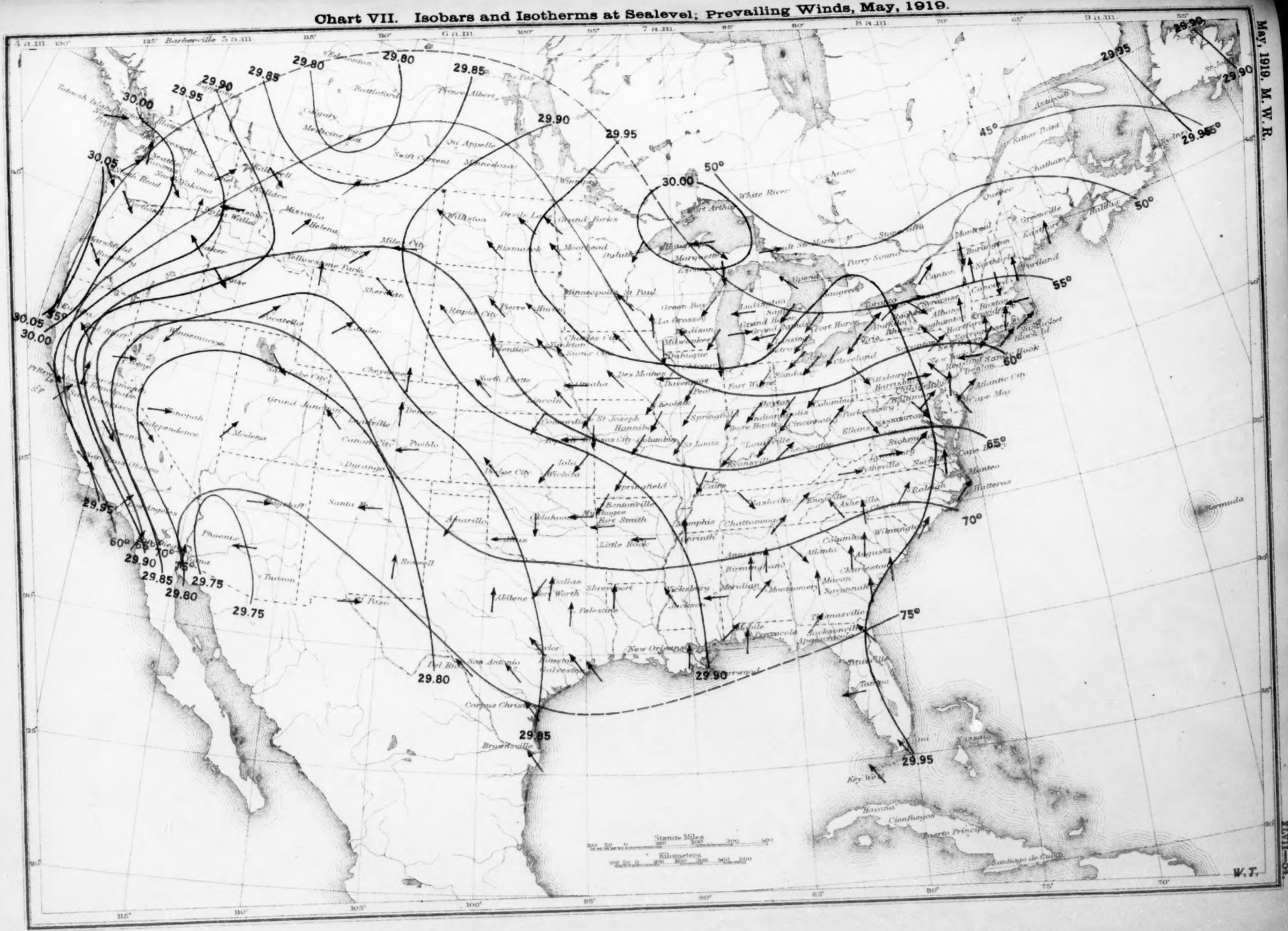


Chart IX. Weather Map of North Atlantic Ocean, May 12, 1919.
(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, May 12, 1919.

(Plotted by F. A. Young.)

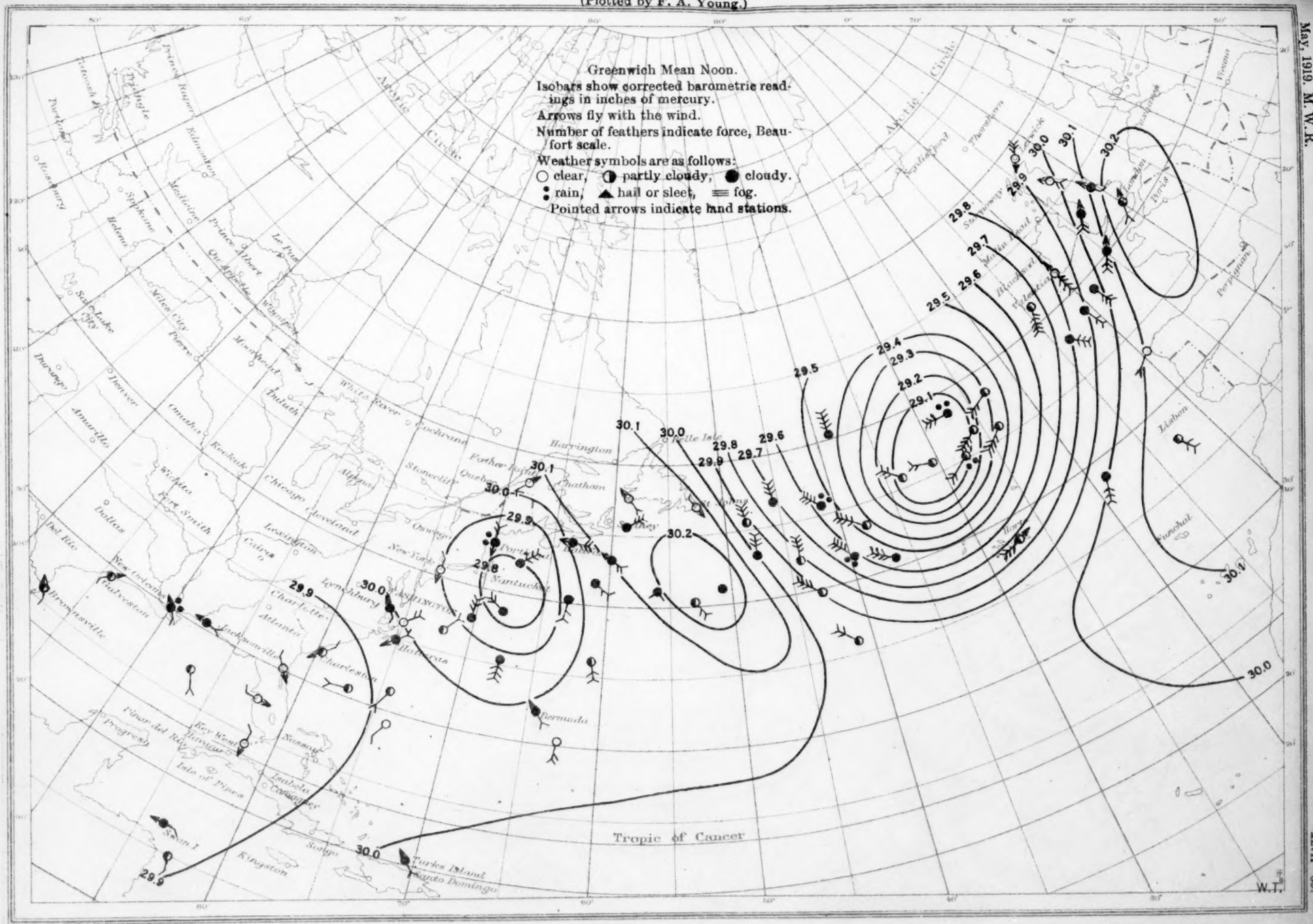

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy.
: rain, ▲ hail or sleet, ≡ fog.
Pointed arrows indicate land stations.
Tropic of Cancer
W.T.

Chart X. Weather Map of North Atlantic Ocean, May 13, 1919.

(Plotted by F. A. Young.)

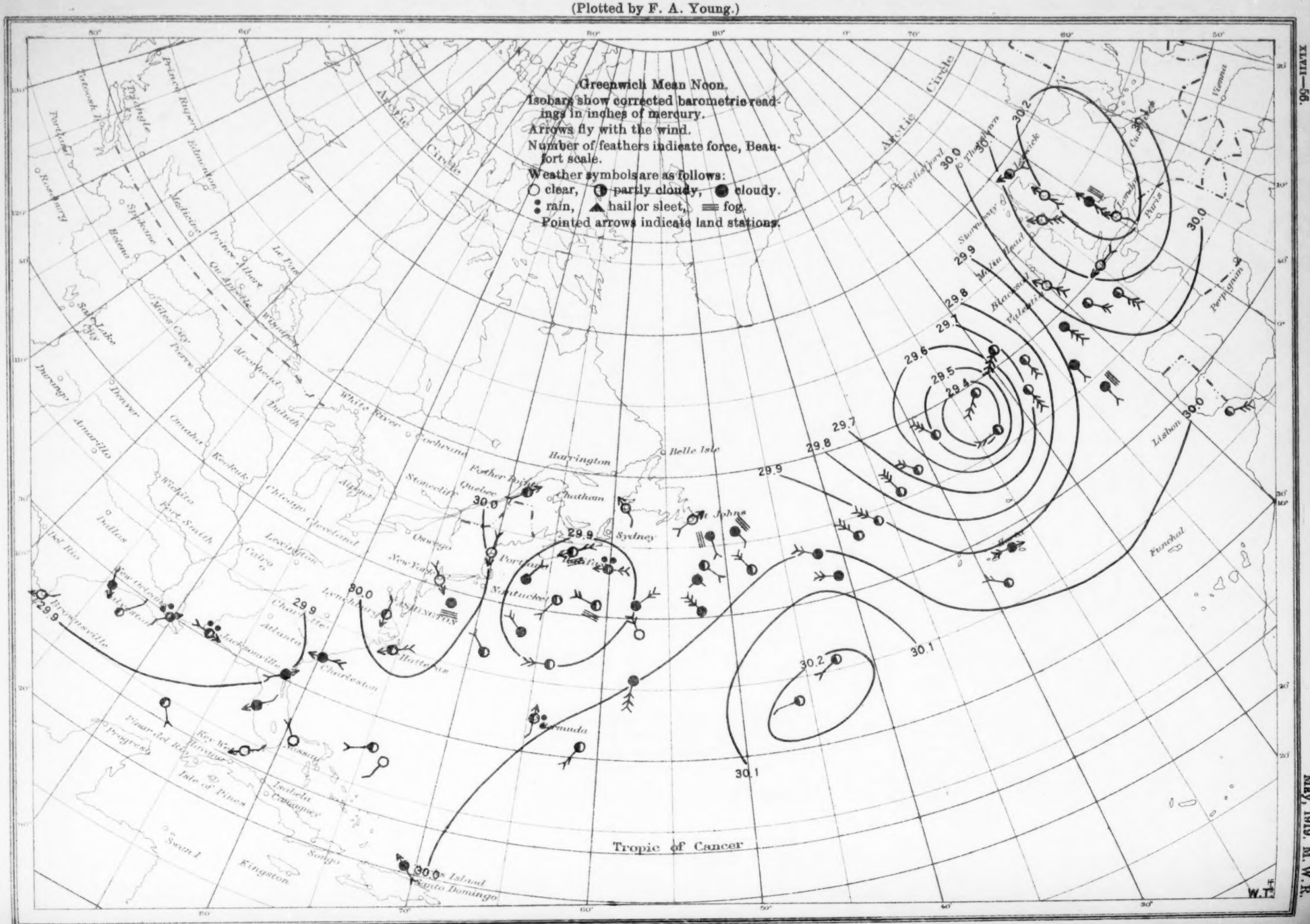

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy.
rain, hail or sleet, fog.
Pointed arrows indicate land stations.
Tropic of Cancer
W.T.

Chart XI. Weather Map of North Atlantic Ocean, May 14, 1919.

(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, May 14, 1919.
(Plotted by F. A. Young.)

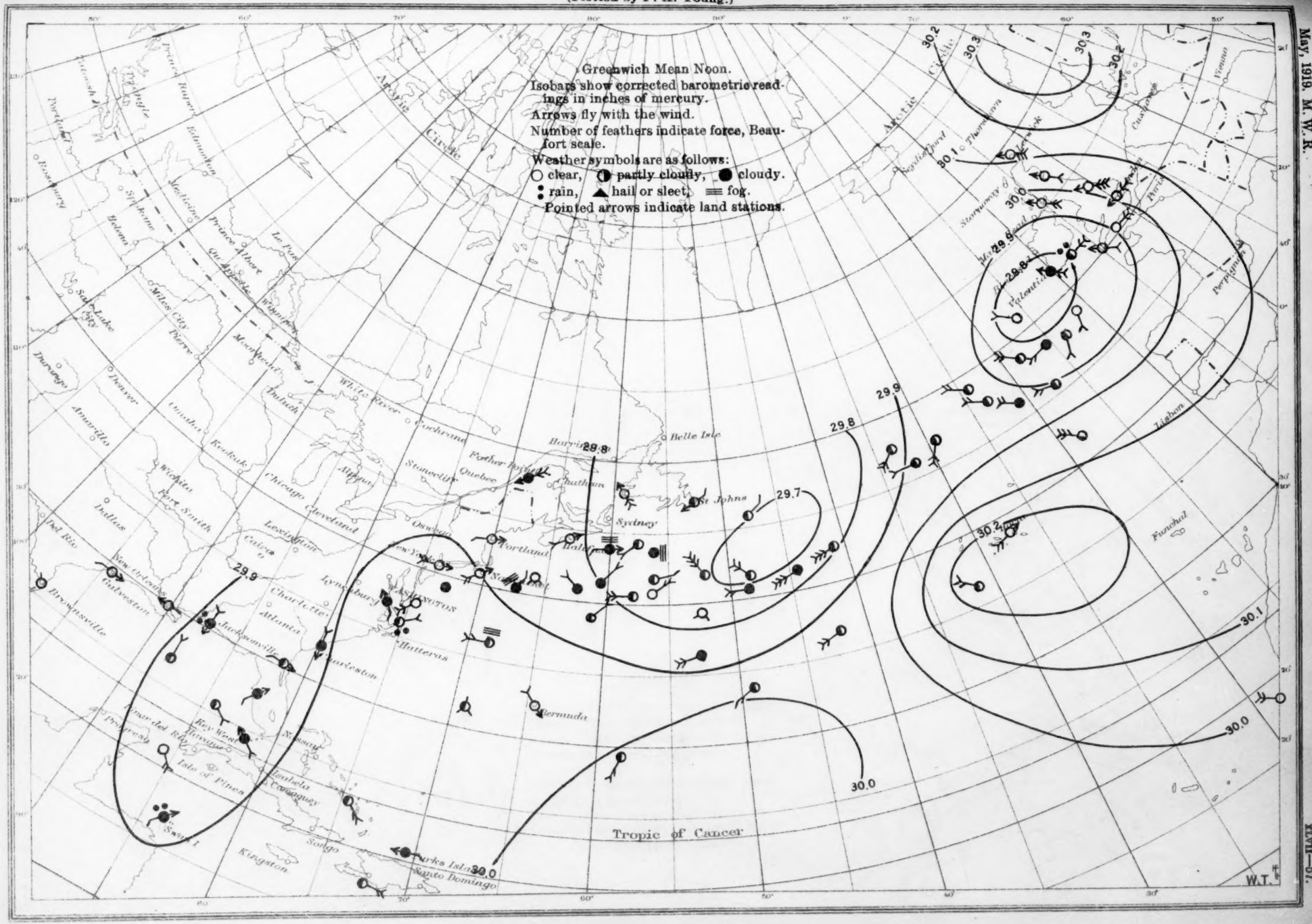


Chart XII. Weather Map of North Atlantic Ocean, May 15, 1919.

(Plotted by F. A. Young.)

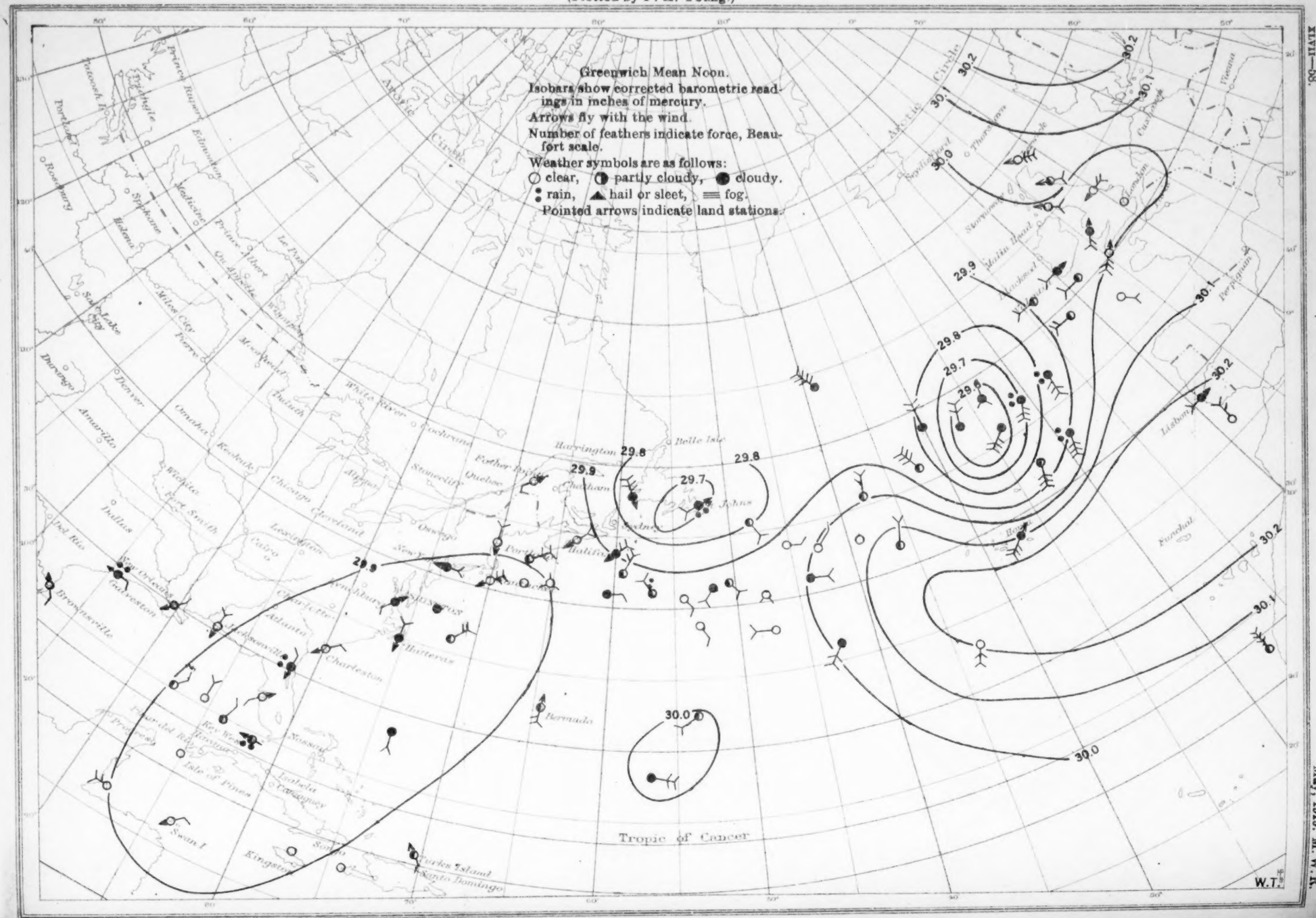


Chart XIII. Weather Map of North Atlantic Ocean, May 16, 1919.

(Plotted by F. A. Young.)

Chart XIII. **Weather Map of North Atlantic Ocean, May 16, 1919.**

(Plotted by F. A. Young.)

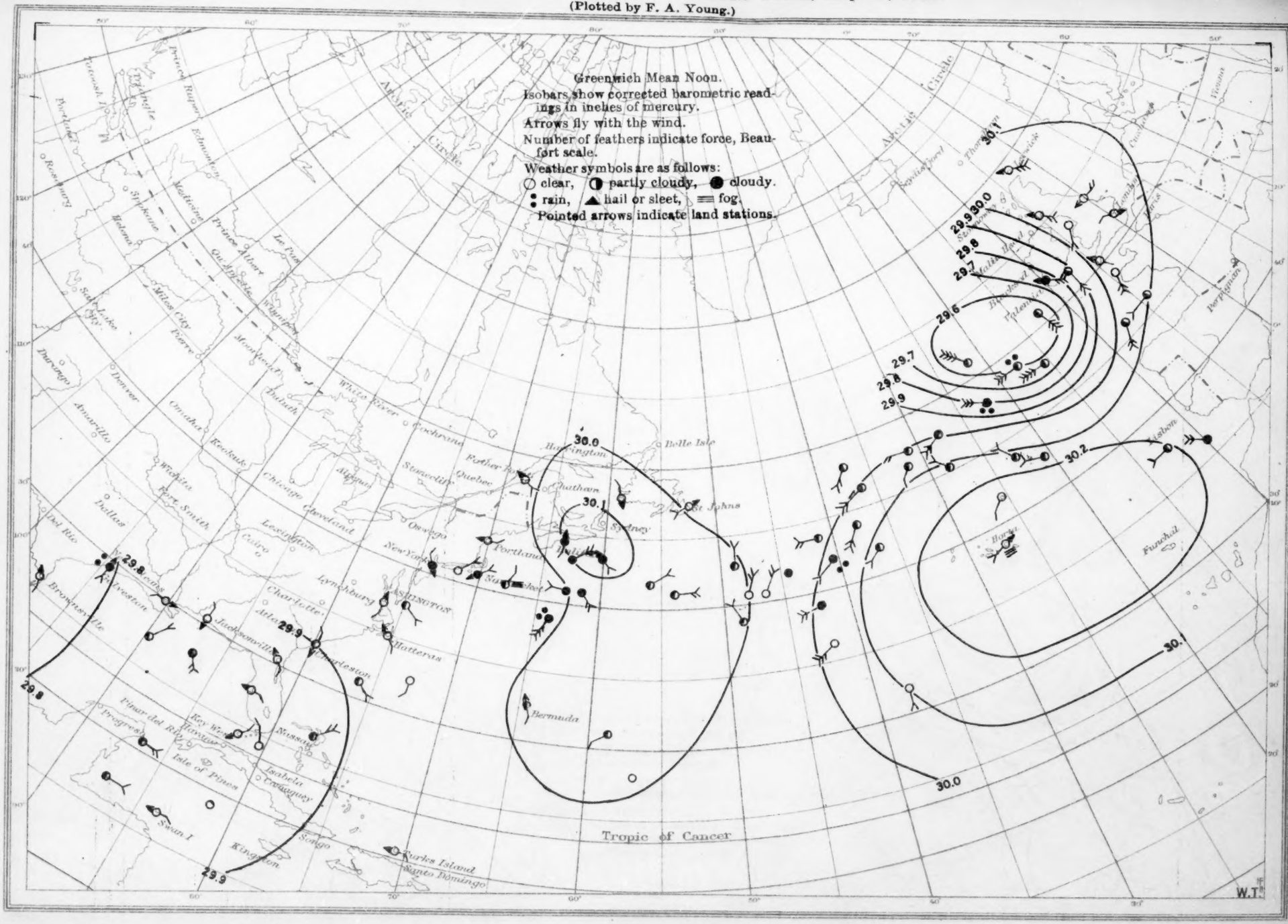


Chart XIV. Weather Map of North Atlantic Ocean, May 17, 1919.

(Plotted by F. A. Young.)

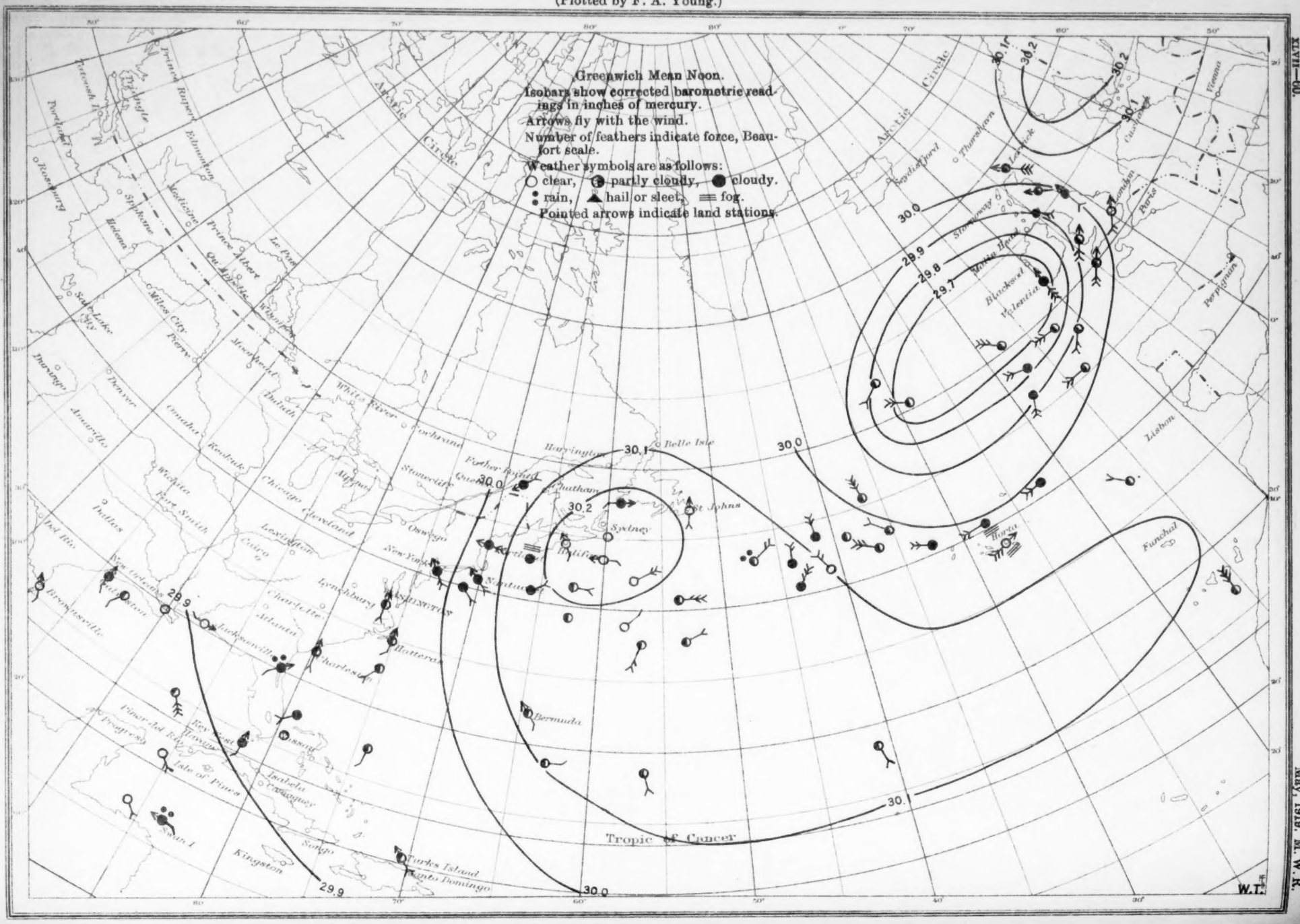


Chart XV. Weather Map of North Atlantic Ocean, May 18, 1919.

(Plotted by F. A. Young.)

Chart XV. Weather Map of North Atlantic Ocean, May 18, 1919.

(Plotted by F. A. Young.)

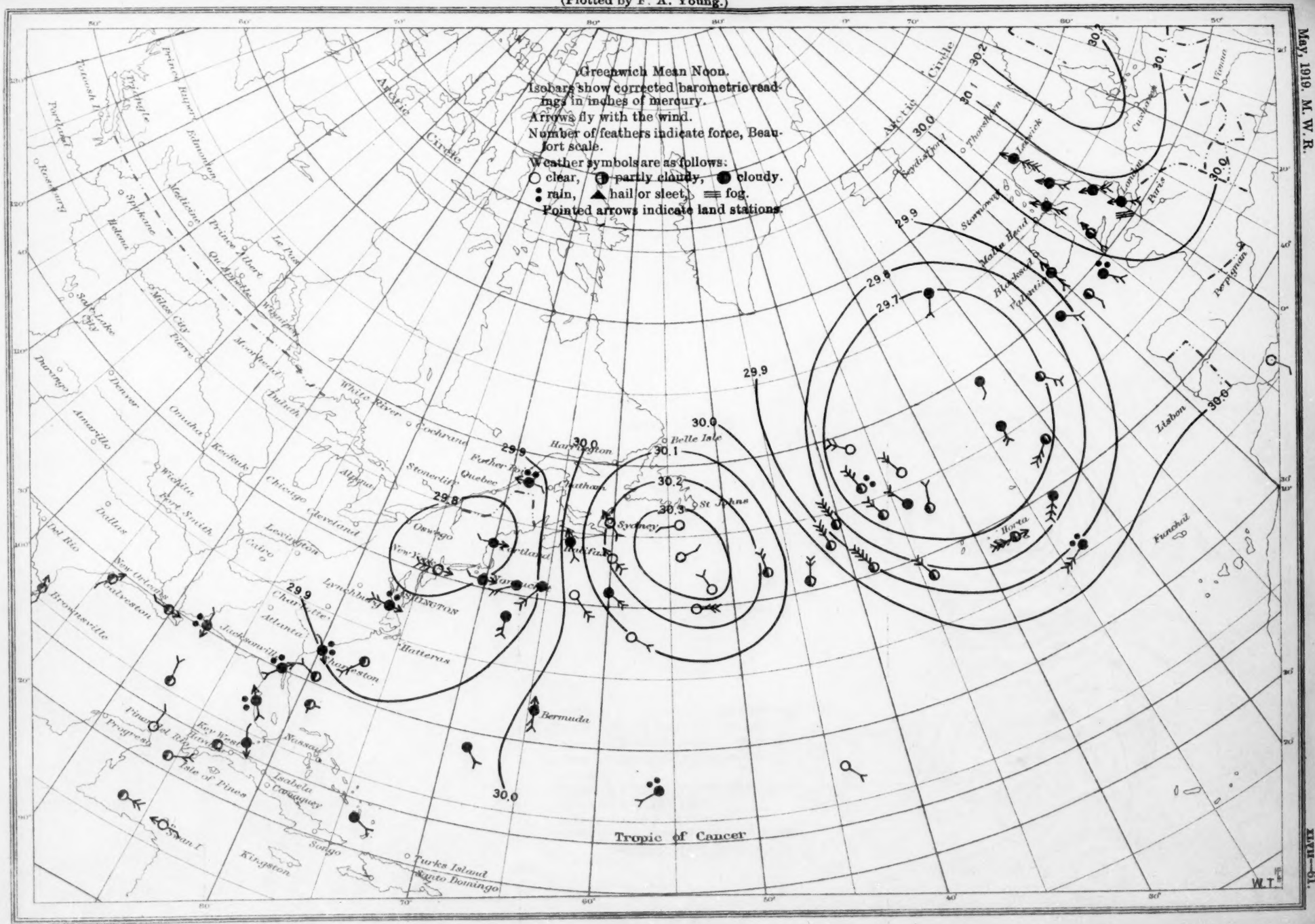


Chart XVI. Weather Map of North Atlantic Ocean, May 19, 1919.

(Plotted by F. A. Young.)

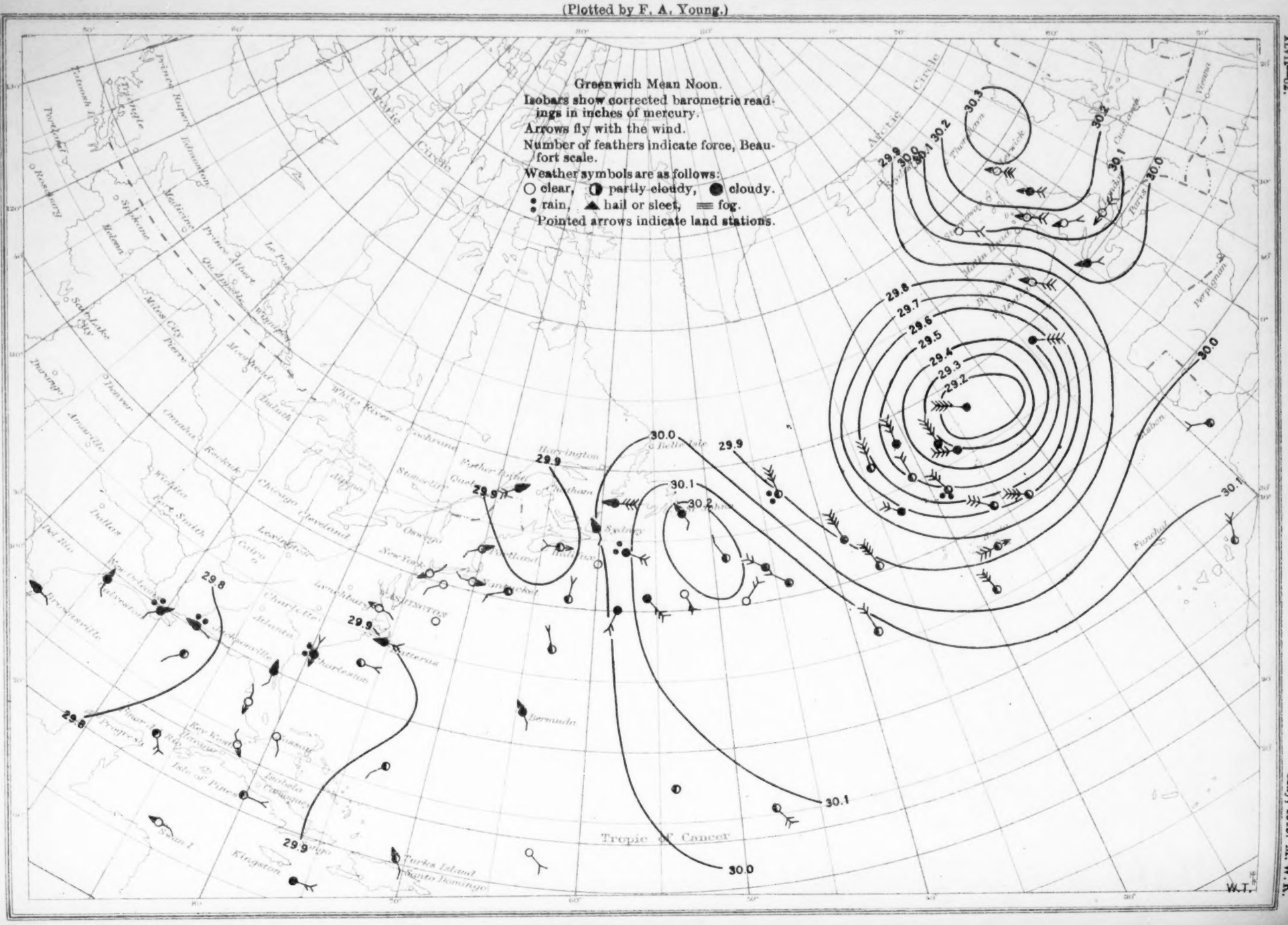

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy.
• rain, ▲ hail or sleet, ≡ fog.
Pointed arrows indicate land stations.
Arctic Circle
Tropic of Cancer
W.T.

Chart XVII. Weather Map of North Atlantic Ocean, May 20, 1919.

(Plotted by F. A. Young.)

Chart XVII. Weather Map of North Atlantic Ocean, May 20, 1919.

(Plotted by F. A. Young.)

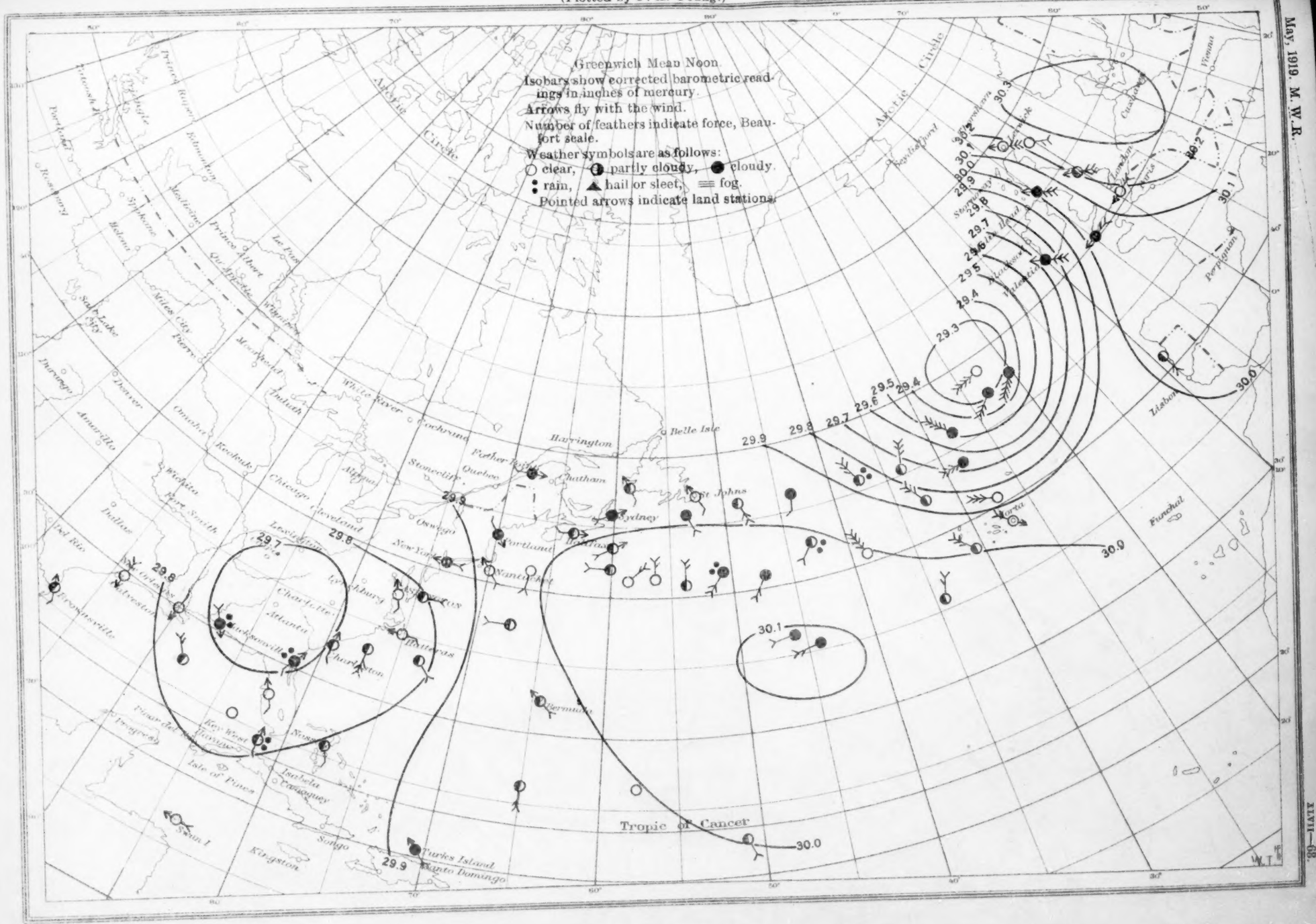


Chart XVIII. Weather Map of North Atlantic Ocean, May 27, 1919.

(Plotted by F. A. Young.)

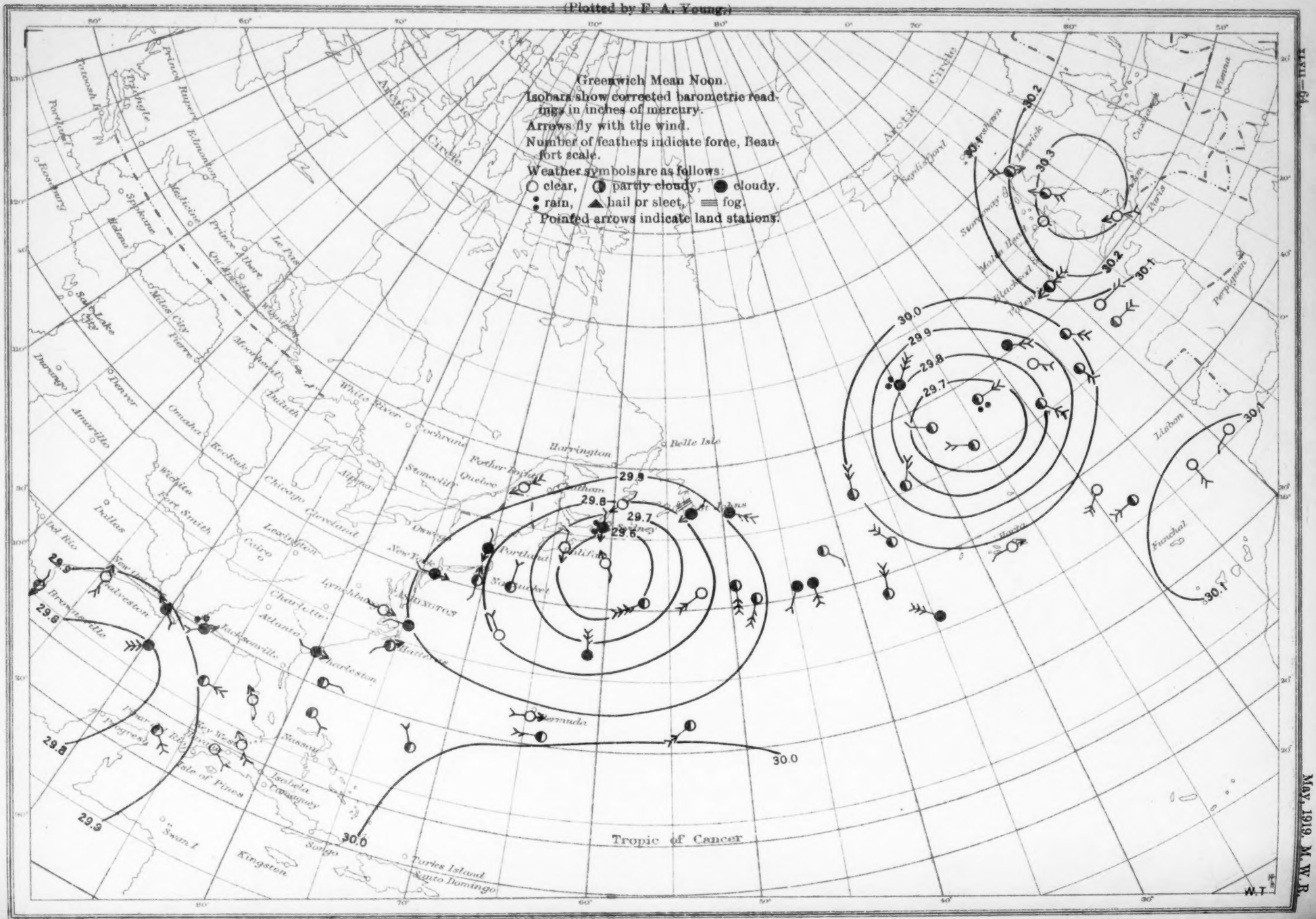
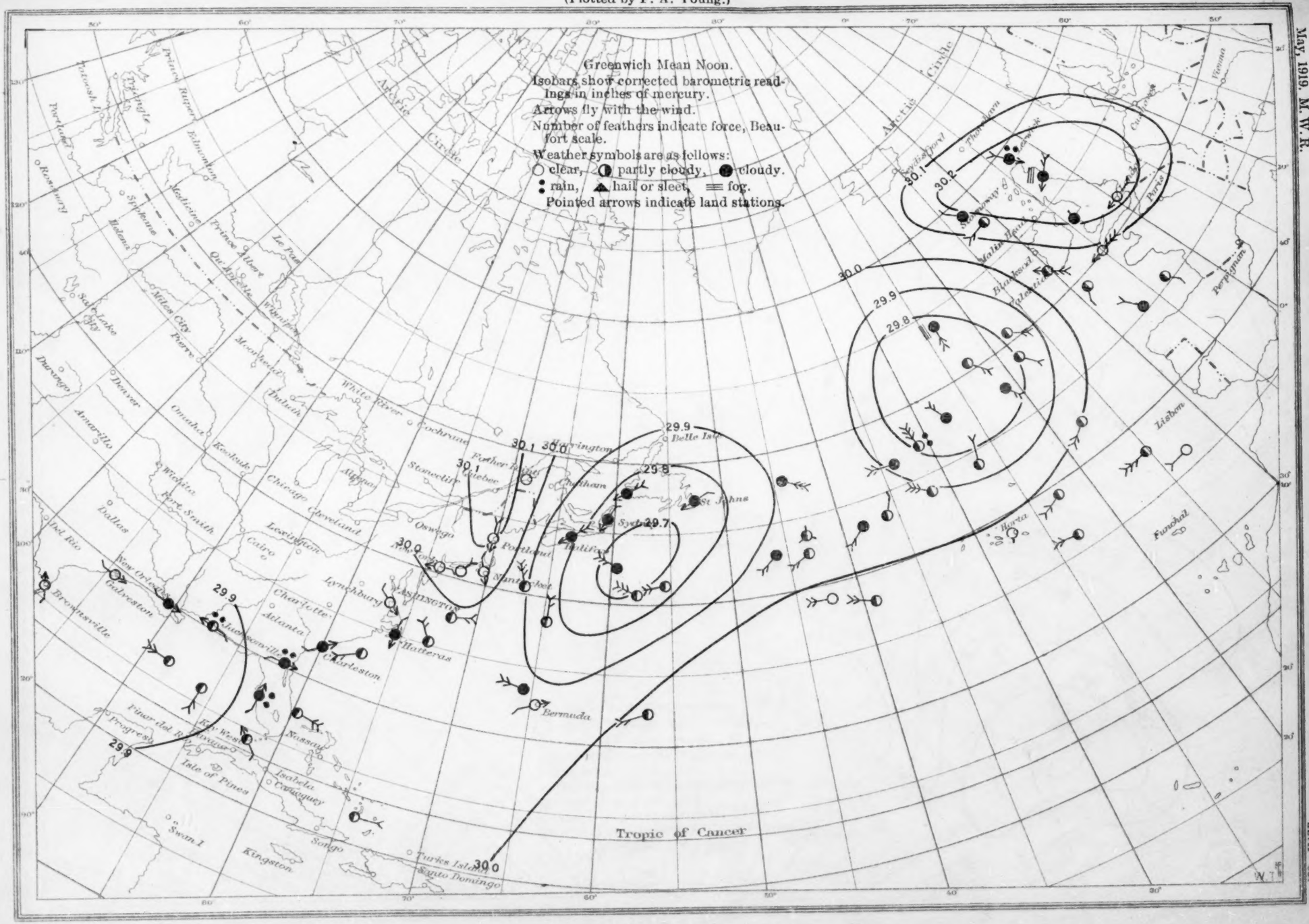


Chart XIX. Weather Map of North Atlantic Ocean, May 28, 1919.

(Plotted by F. A. Young.)

Chart XIX. Weather Map of North Atlantic Ocean, May 28, 1919.

(Plotted by F. A. Young.)



May, 1919. M. W. R.

XLVII—65.

Chart XX. Weather Map of North Atlantic Ocean, May 29, 1919.

(Plotted by F. A. Young.)

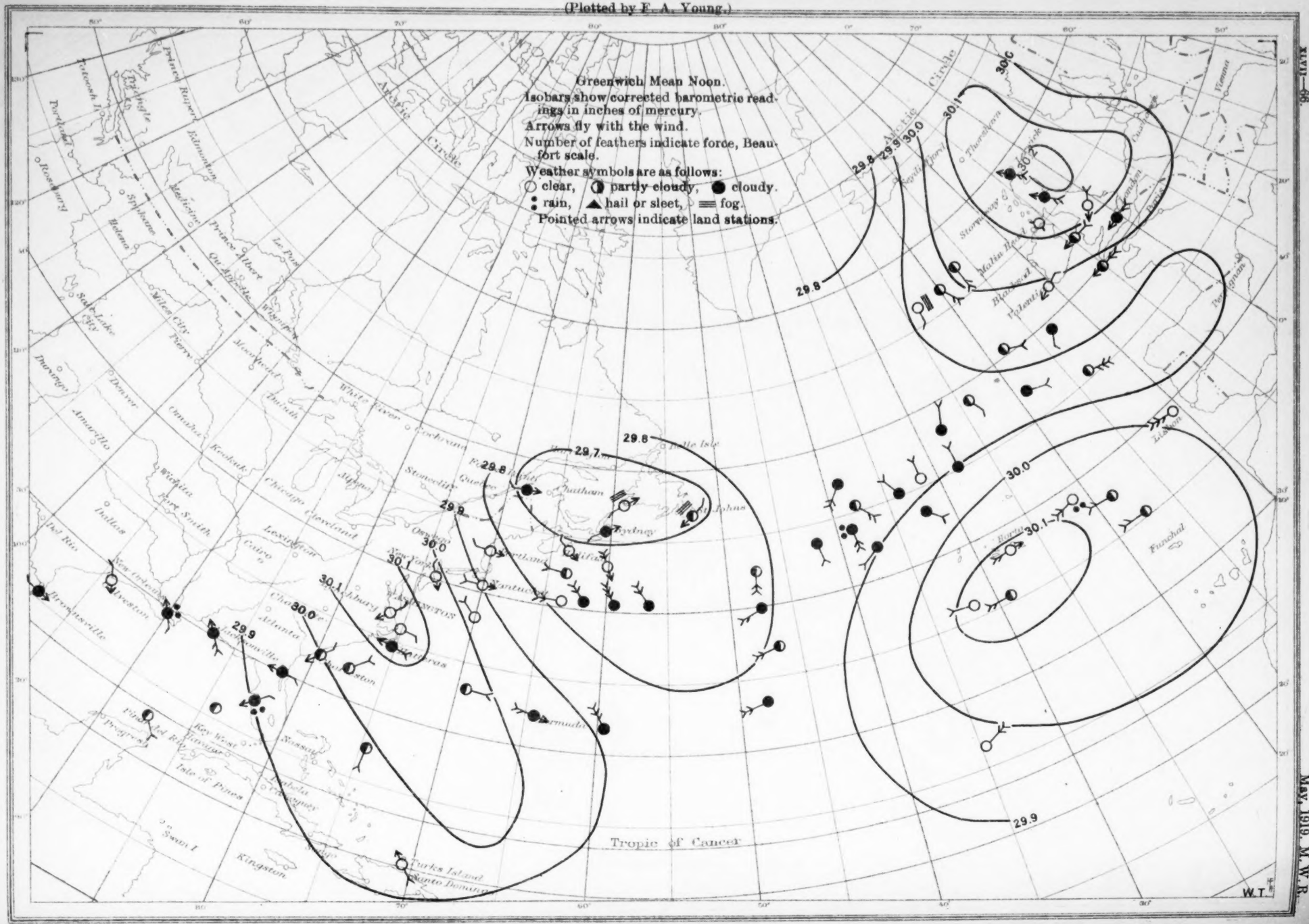


Chart XXI. Weather Map of North Atlantic Ocean, May 30, 1919.

(Plotted by F. A. Young.)

Chart XXI. Weather Map of North Atlantic Ocean, May 30, 1919.

(Plotted by F. A. Young.)

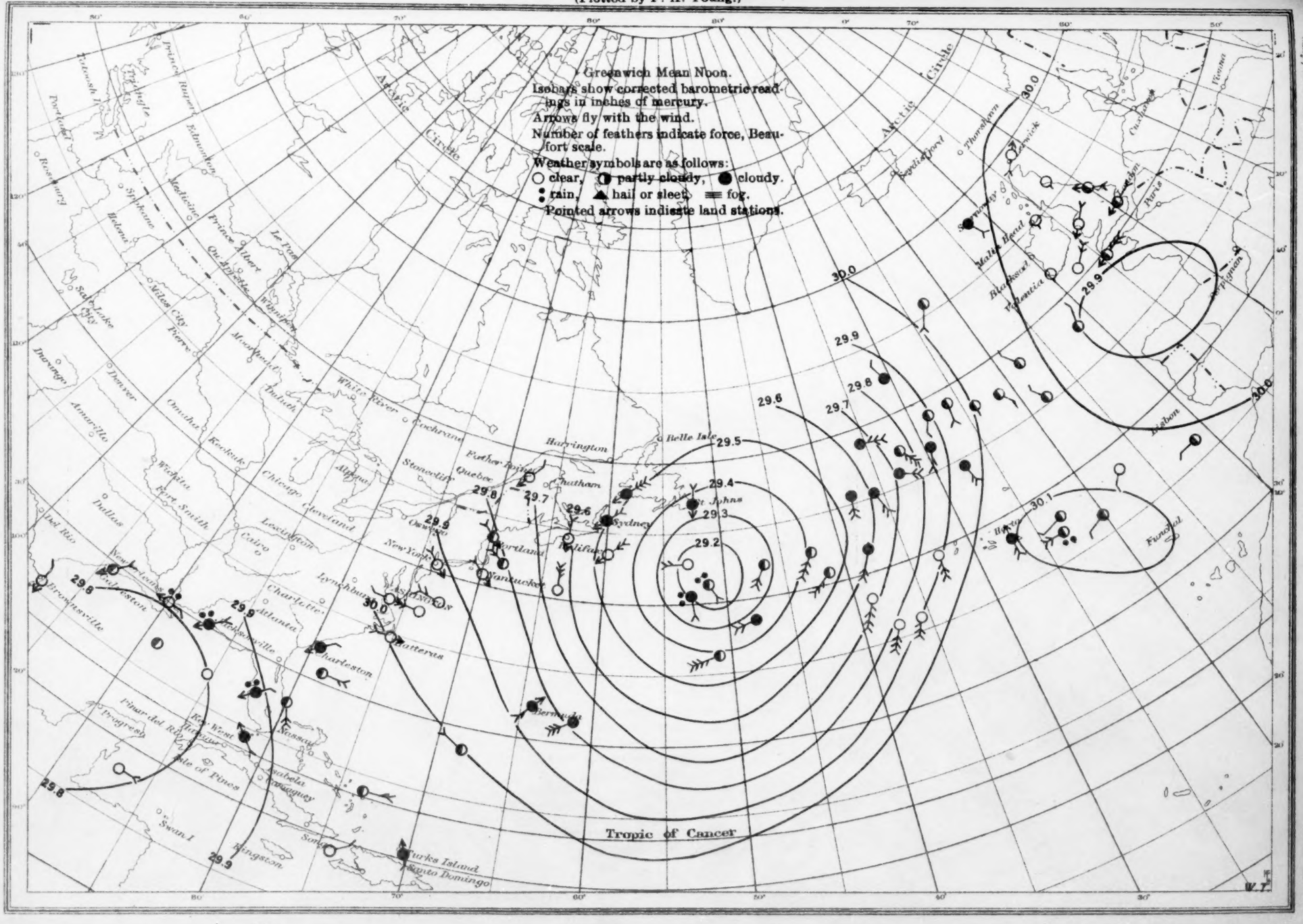
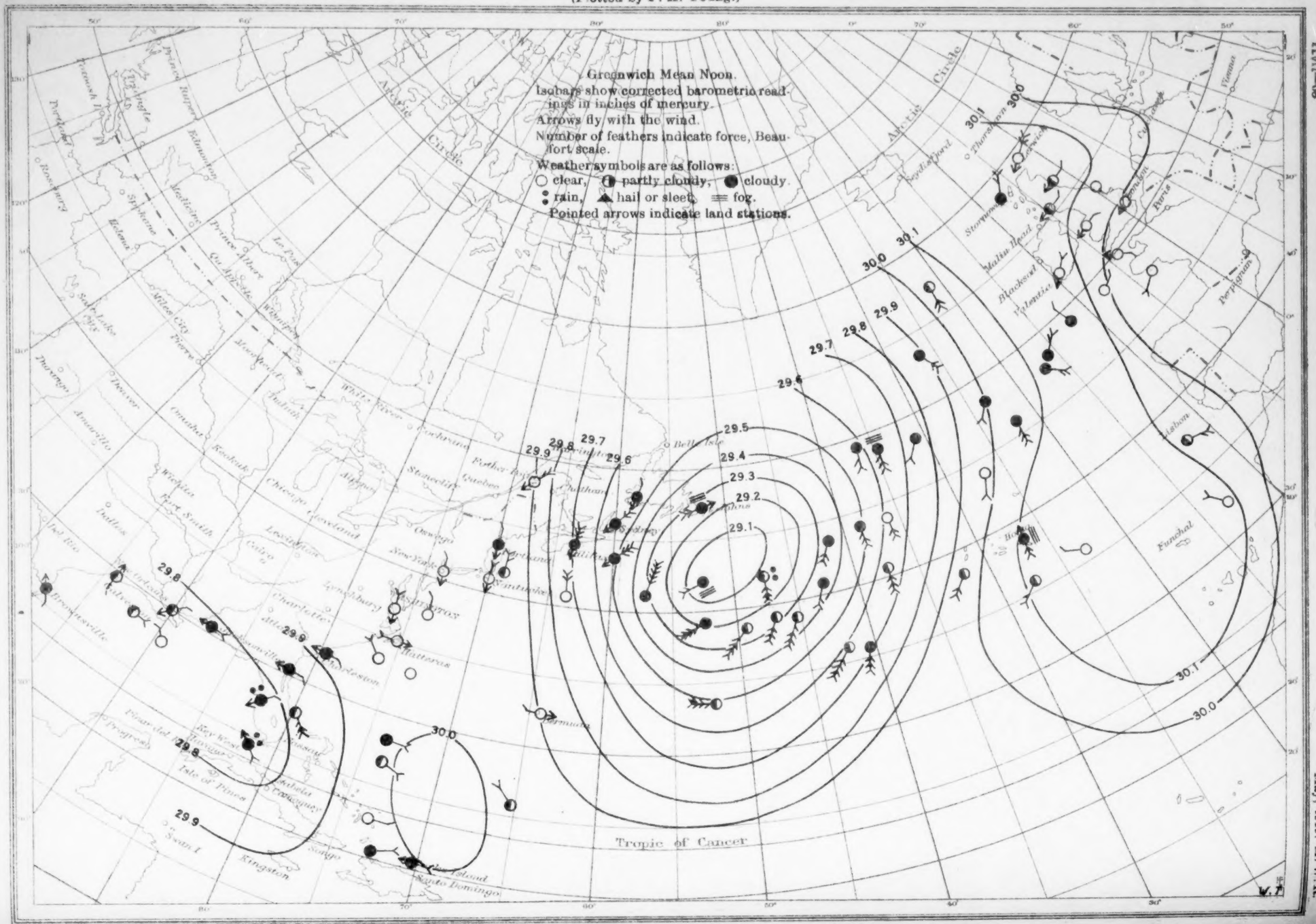


Chart XXII. Weather Map of North Atlantic Ocean, May 31, 1919.

(Plotted by F. A. Young.)